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CONTENTS

PATTERNS IN THE INTEGUMENTS OF FAST-SWIMMING FISHES

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[Article by S. V. Pershin, O. B. Chernyshov, L. F. Kozlov, A. P. Koval' and V. A. Zayets]

[Text] Fast fishes are of great scientific interest because their relative swimming speed is sometimes much higher than that of such fast marine mammals as dolphins and whales (1, 30, 35, 37). Note: Those fishes are usually considered fast whose swimming speed is more than ten body lengths (L) a second, i.e., u_m greater than 10 L/sec. However, this is not always applicable to large fishes and, moreover, the length of time a fish swims at high speed must also be taken into account. Fast fishes are readily distinguishable from the upper boundary of a field of points on a generalized 4-parameter graph (32). It is important to note that only a few dozen of tee 24,000 to 25,000 fish species now alive are regarded as fast and even fewer are large (L greater than 1.0 m). This simplifies the task of selecting fast species for bionics research (31).

High swimming speeds are due to the high power-to-weight ratio and low hydrodynamic resistance of fast fishes with partial laminarization of the boundary layer (12, 15, 16, 23, 33). The power-to-weight ratio in fishes is determined by the total body weight and the power of live propellers, i.e., muscles which make up a substantial fraction (about two-thirds) of the body weight and the larger the fraction, the higher the swimming speed. There are also some obvious characteristics of low hydrodynamic resistance: folds tucked into special lateral pockets and dorsal fins; arrow-shaped fins, including the caudal fin, the main propeller; a well-streamlined body, including laminar shapes (32). The last fact indicates that fast fishes utilize the means of streamlining the boundary layer which were created in the course of evolution.

The optimization of body shapes and tail propeller of fast fishes of low resistance are considered in (33). Figure 1 shows large fast fishes belonging to three groups in a hydrodynamic classification proposed by the authors, namely (from bottom to top): I--thin-bodied, elongated, with an ogival head (mako shark and wahoo); II--thick-bodies, short, streamlined shape, with an elliptical head (tunny); III--specific forms with a conical head and long break, sword, or

spear (e.g., the swordfish whose beak is one-third its total length). All these fishes have the same type of fairly elongated caudal fin, which is the main propeller. On the other hand, a study of the integuments of these three shape-discriminated groups of fast fishes showed that the skin, scales, and slime differ markedly from group to group.

Let us compare the swimming ability of fast fishes and dolphins. Nonstationary swimming of many species of living organisms, including eel-like fishes, can be mathematically explained by the creation of tractive force following the wave-like motion of a flexible rod in a solid [sic] medium (24). The large fast fishes under study belong to the Scombroidea. No experimental data on the kinematics of swimming are available for evaluating the swimming of these fishes on the basis of the hydrodynamics of a thin deformable body (25). Let us apply the rough energy estimate used to determine the decrease in hydrodynamic resistance of various dolphin species (34).

Let us compare a common dolphin 2.0 meters long, mako shark 2.0 meters long, tunny 2.0 meters long, and swordfish 3.0 meters long including its beak. Their observed maximum swimming speeds are 13, 15, 20, and 25 m/sec and the power-to-muscle weight ratios 29.7, 37.5, 88.2 and 78.0 kg [sic], respectively. Calculations showed that the observed swimming speeds of these large fishes with $Re_L = (2.6 \text{ to } 6.6) \times 10^7$ are in the interval between the estimated speeds with completely laminar and turbulent flows of the boundary layer. This means that in the fishes under study either the laminar boundary layer persists for a considerable part of the body length or friction drag decreases significantly within a turbulent boundary layer. The mechanism responsible for the decrease in resistance differs in the various species of fast fishes, but the integuments that come into direct contact with the water flowing around them are undoubtedly involved.

The authors used in their study 20 species of river, marine, and oceanic fishes (about 100 specimens). They included: fast bony fishes--trout, pike, scad, bonito, wahoo, little tunny, yellowfin tuna, sailfish, and swordfish; fast cartilaginous fishes--blue shark, tope and mako (mackerel); and for comparison slow fishes--burbot, ruff, perch, Don ruffe, white bream, roach, pickerel, and Black Sea spiny dogfish. The length of these fishes varied from 0.15 to 2.60 meters, $Re_L = 2 \times 10^5$ to 5×10^7. The skin structure, scales and secretory apparatus were investigated in most of them. Their histological structure, properties, and interrelations were studied through the examination of more than 4000 microscopic specimens. The fishes were caught, fixed, and frozen during field trips to the Dneiper River, Black Sea, and Atlantic Ocean.

Unitl recently and with rare exception, fish skin and its derivatives--scales and the secretory apparatus--were studied only in slow flow bony fishes with a Reynolds number equal to or less than 10^5. According to the literature and the results of our investigations, the histological structure of their skin is fairly similar, despite the differences in body shape and swimming speed. The skin of slow bony fishes, like that of all vertebrates, consists of three main layers: epidermis--thin external layer; corium--the skin proper, a thick middle layer consisting chiefly of collagenous bundles and fibers; and subcutis--the lower layer of loose connective tissue, which frequently contains numerous fat cells.

The main function of fish skin is to protect the body against mechanical and other injuries. Additional protection is provided by the scales and slime released by special slime-producing cells.

We studied the histological structure of the skin of bony fishes in detail, according to a single topographic scheme, in 15 to 30 parts of the body, in different cross sections and in each cross section on the back, side, and ventral portion of the body. The material was fixed in 10% formaldehyde and Bouin's fluid. The histological sections were 5 to 10 microns thick (20 to 25 microns in the case of sharks).

We found that the skin of fast fishes consists of the same three main layers as in slow fishes, but its histological structure is much more complex. The skin of fast fishes contains various structures lacking in slower forms, some of which we were the first to describe, such as a pigmented fibrous layer in tunas and swordfishes, and a fibrous stratum and specific combination of skin with muscles in the mako shark. Thus, the structure of the integuments of the various fast fish species has specific features peculiar to each group (9, 10, 18-20). We also found that while the structure of the skin in fast species differs significantly from one part of the body to another, these species exhibit definite patterns in this respect. In the following paragraphs, we shall describe the structure of the skin taken chiefly from the middle of the trunk.

A generalized histological cross section of the corium in specimens from the last bony fishes under study is as follows (from the epidermis to deep in the skin): a thick basal membrane (several thousandths of a millimeter); a specific pigmented fibrous layer (hundredths of a millimeter); a well-developed corium (total thickness about one millimeter or more) and a rather well-developed subcutaneous layer with a fairly large number of fat cells found only in certain species.

Two new layers not occurring in small slow species can be distinguished in the skin of bonitos: the above mentioned pigmented layer in the corium, and a very distinct layer of subcutaneous fatty tissue, the subcutis. This second layer is one millimeter thick in the little tunny but is absent in the yellowfin tuna; on the other hand, the corium of the latter is very well developed and it consists of a dense layer of collagenous bundles (about five millimeters thick). The skin of the bonito has features both similar to and different from that of the little tunny and yellowmouth tuna. Like that of the little tunny, swordfish skin has a thick layer of subcutaneous fatty tissue containing concentrations of loose bundles of collagenous fibers. Like the yellowfin tuna, the corium of the sailfish has a thick layer of collagenous bundles. Analogs in skin structure can be discerned in these similarities and differences which are related to the change in size and shape of the body, swimming speeds, and Reynolds numbers of fast bony fishes due to their mode of living.

Shark skin also has a basal boundary membrane and upper, main, and lower layers of the corium. Between the corium and the subcutis is an elastic membrane formed of elastic fibers arranged lengthwise (it occurs only in sharks). A large quantity of an amorphous substance and loosely arranged fibrous elements in the upper layer of the corium are characteristic of the skin of slow sharks. However,

there is less of the amorphous substance in the lower layers of the corium and distinct solid strata of collagenous bundles are predominant. The faster a shark swims, the greater the number, thickness, and density of these strata, and they acquire a compact and ordered structure. The numerous strata of collagenous bundles and fibers lie parallel to the body surface in the form of a small network. The direction of the fibers in the adjacent strata is orthogonal and together with the long axis of the body it forms an angle of about 45° (35 to 40° in the tail) (2, 40). There is also a similar diagonal arrangement of the fibers in the corium of bony fishes.

The diagonal arrangement of the collagenous fibers (which support the corium of sharks) along right and left spirals at a 45° angle to the long axis of the body is an optimal arrangement for swimming fishes when making bending and oscillatory movements. This is shown by a comparison of the solutions to two problems in the theory of resistance of materials reinforced by polymeric cord (39). A round 2-layered rubberized-cord cylinder is deformed by internal pressure in different ways, depending on the angle α at which the threads of the cord lie in relation to the long axis of the cylinder. When α_1 is about equal to 35°, the shape of the casing remains cylindrical. An angle of α_2 of about 50 to 54° satisfies the optimal conditions of fatigue strength of cord threads in rubberized-cord automobile tires subjected to the variable stresses that arise when the sheets are rolling. As for the arrangement of the network of collagenous fibers in shark skin, $\alpha = (\alpha_1 + \alpha_2)^{-2}$, i.e., the conditions are satisfied for the least deformation of the skin with reticulated reinforcement and for the least fatigue strength of the collagenous bundles and fibers of this network.

Analysis of the change in histological structure of the skin of bony and cartilaginous fishes in relation to an increase in the Reynolds number from 2×10^5 to 5×10^7 reveals the following general tendency: The epidermis becomes more and more multilayered with increasing size of the fish and it releases steadily larger quantities of slime into the boundary layer. This is consistent with the arrangement of fishes by Re_L.

Another general tendency in the development of the skin of fishes with increase in the Reynolds number is the limitation of mobility of the associated layers of skin by the mutual penetration of tissues. This tendency is manifested in varying degrees from one species of fast fish to another. Let us present some facts.

The little tunny, yellowfin tuna, and sailfish have more or less distinct folds, especially in the upper part of the trunk, at the place where the epidermis joins the basal boundary membrane, thus increasing the cohesion between the two upper layers of skin and preventing the epidermis from separating when great shear stress is placed on their bodies.

Microphotographs of histological sections of the corium of the bonito (Figure 2) and all tunas clearly show the transverse and slanting connective tissue bundles, which depart from the basal boundary membrane, pierce the pigmented fibrous layer, and penetrate into the second connective tissue layer, the corium proper. The peculiar pigmented fibrous layer consisting of lamellar structures with a loose amorphous mass between them parallel to the body surface appears to be

reinforced and quite rigid, while the basal membrane above, and the corium proper below, are tightly secured to each other.

The tail of the tope and mako shark does not have a subcutis. The collagenous bundles are densely intertwined in the lower layer of the corium with muscle bundles of the skeletal musculature (10), at an angle to the long axis of the body (Figure 2.b.). The complex musculocutaneous system strengthens the skin and enables it to participate actively in the movements of these sharks.

An important mechanical characteristic of the integuments of fast fishes is the skin mass, determinable by its thickness. As the Reynolds number increases to 5×10^7, the relative thickness of the skin in most large fast fishes, bony and cartilaginous, decreases from 1×10^{-3} to 7×10^{-4}, i.e., by a factor of 1.5 (Figure 3). However, there are also mutually exclusive ex eptions: in the little tunny and blue shark, the skin is almost three times thicker than "normal" for most large fast fish, whereas in the thin-bodied, elongated wahoo, it is less than half as thin at the same Reynolds number. Thus three types of skin can be distinguished among large fast fish on the basis of thickness: thick, medium, and thin. The bonito, which occupies an intermediate position with respect to the structure of its skin, is found at the point of branching in the graph in Figure 3.

The following species belong to the most numerous group of fast fish with relative medium thickness of the skin: trout, bonito, yellowfin tuna, sailfish, swordfish, tope, and mako. According to the available qualitative data on fish skin, this group also includes other species of scaly tunas with a body length of L greater than 1.0 meters (bluefin tuna, albacore, bigeye tuna) as well as some marlin and spearfish species, i.e., the group embraces the largest fast fishes. A feature common to the integuments of all these highly varied species of fast fish is the presence of scales and abundant slime, the latter a major factor in decreasing the hydrodynamic resistance of the above-named species.

In addition to the little tunny, the fast fishes with comparatively thick skin include skipjack tuna, mackerel-like tuna, blue shark and the Greenland shark (according to the literature). The common features of the integuments of the above-mentioned tuna species are the smooth surface of the skin and the absence of scales and slime. The common dolphin appears to be a natural continuation in the series of tuna and shark species arranged by Reynolds number and relative skin thickness ($Re_L = 2 \times 10^7$ and t/L of about 9×10^{-3}) (Figure 3, point 12). A smooth skin surface and absence of slime are also characteristic of dolphins, which were found to have a self-adjusting damping capacity (34).

It is reasonable to assume from the above that hydrodynamic resistance is reduced in the bonito, little tunny, and swordfish by the damping capacity of the skin, specifically, by its pigmented fibrous layer. The latter contains a loose amorphous mass and it is several times thicker than the layers of skin below. However, the mechanism of damping by fish skin must be distinguished from that by much thicker skin by its different structure, absence of a papillary layer in the corium, and by the fact that blood pressure in cold-blooded organisms is one-tenth that in aquatic mammals. Hence the damping capacity of the skin of fast

fishes must be less efficient than that of dolphins. This is confirmed particularly by the fact that none of the tunas without scales and slime grow to a large size (L less than 1.0 meters) or swim as fast as the larger scaly, slime-producing tunas. The efficiency of the damping action of fish skin warrants special study.

The relatively thin and small skin mass of the wahoo is consistent with its low power-to-weight ratio which barely equals that of the dolphin, although the wahoo's top swimming speed is much greater than the dolphin's. It is reasonable to assume that the traveling wave effect on the skin reduces the hydrodynamic resistance of the wahoo (27, 28). It follows, from the theory of the traveling wave on a flexible body moving forward in an ideal fluid, that, with oscillations of the plate and cylindrical casing, their rigidity is proportional to the cube of the thickness of the skin (27). Therefore, if fast fishes use the effect of the traveling wave, it is most energy-efficient for fishes with the thinnest skin, a condition satisfied by the wahoo. It will be noted that the absolute thickness of wahoo skin (0.45 millimeters in a fish longer than one meter) is approximately the same as in the smaller bonito. Cases of propagation of periodic low-amplitude waves have been observed on the skin surface of freshly caught (by commercial fishermen) bonitos with intact skin. The question of the traveling wave on the bonito is worth further investigation.

The great majority of fishes have scales (7, 8, 18, 41). Scales, together with skin, form the external skeleton and perform protective and some other functions (2). They [the scales] vary from species to species with respect to distribution on the body, position in the skin, structure, shape, size, [the fishes] mode of life, [fish] body size, and [fish] swimming speed. We studied scales in intact fixed specimens from the above-mentioned species. Using a binocular magnifying glass and microphotography, we investigated the topography, relative position, and relative size of the scales. As a result, we also discovered hydrodynamic functions and patterns of change in the scales, including those of fast [fish] species.

The body of bony fishes is usually covered with scales of the cycloid or ctenoid type. The scales are covered on the outside by a thin and, in some species, thick layer of connective tissue and epidermis containing many secretory cells that release a slimy substance which separates the body of the fish from the water. There are species completely lacking in scales and species in which scales appear only on certain parts of the body as in scaleless tunas (they have scales only in the anterior part of the trunk in the form of a corset unique to tuna).

The scales of some large fast bony fishes are unusual in several respects. In the bonito, they are small and reduced. They are covered on top by a fairly thick layer of connective tissue and epidermis and, consequently, the slime-covered body is very smooth to the touch. In the yellowfish and other scaly tunas, the scales are larger, but these fish attain a fairly large size. Since the scales are embedded deep in connective tissue, the body surface of tunas is exceptionally smooth. In the sailfish, marlin, and spearfish, the scales vary in shape in different parts of the body. There are four main shapes: tear-shaped, wedge-shaped, lanceolate, and threadlike (20). These scales, unlike those of other bony fishes, are not continuous; i.e., there are spaces between the rows.

Large but thin and flat tear-shaped scales with a round base, an elongated, pointed end and arranged in separate, distinct longitudinal rows, are found on the lateral surface of the sailfish. Each scale in a row lies free, not superposed upon each other, at an angle to the body surface and completely embedded in the dense connective tissue layer of the corium. Over the scales are cover layers about 0.15 millimeters thick. Thus, the surface of the sailfish body when flat is comparatively smooth. However, even when the fish bends only slightly, the free ends of the tear-shaped scales raise the layers of skin above them to form a crest about 0.6 millimeters high, while longitudinal ribbing appears on the convex lateral surface of the body. The ribbing is most pronounced in the center of the body. It gradually decreases toward the head and tail and in every cross section from the middle to the dorsum and abdomen of the fish.

The surface of the skin in the large swordfish is raised with longitudinal folds, depressions, and an apparently secondary slight roughness due to small unique scales (18). The longitudinal folds run from the head to the middle of the body and then gradually decrease. They also change size from the dorsum to the side and then to the abdomen. The raised skin of the swordfish is probably smoothed out in part by a layer of slime from the secretory cells and canals. The shark body is covered by placoid scales arranged in diagonal rows in the direction of the spirals of the connective tissue fibers of the corium. Inflexible longitudinal ribs are usually found on the plates of the placoid scales. The number of these ribs or keels varies from one to three or five, depending on the species. As a result, the placoid cells are very rough, like emery paper, but even a well-streamlined shape has rough elements.

The scaly integument of slow and fast sharks differ significantly in the compactness and size of the placoid scales and keels. In the Black Sea spiny dogfish, for example, the scales are large and relatively far apart (10 per mm^2 in the middle of a one-meter shark). In the fast mako shark, they are closer, often touching one another and forming a solid armor plate with precise diagonal rows. (The scales are small with 50 per mm^2 in the middle of a one-and-one-half meter shark.) The height of keels decreases proportionately from 100 to 25 micrometers. Moreover, the keels of the scales in fast sharks go in the same direction as the preceding ones, seeming to form over the entire body surface almost continuous longitudinal microribs resembling the above-described ribbing on the sailfish and the longitudinal skin folds on the swordfish.

Despite the extremely varied types of scales, a relative decrease in the size of the scales with an increase in the Reynolds number is characteristic of the general tendency. It is shown in (6) that the size of the scales is functionally related to the degree of mobility of the fishes, but the decrease in size of the scales with increasing length of the fishes is due solely to the greater flexibility of the body. Our further analysis of the data revealed that a hyperbolic relationship exists between the relative maximum swimming speed $\bar{u}_m = u_m/gL$ and relative length of the scales l/L (l - length of a scale, L - length of the fish). We found that in the case of slow freshwater fishes (bream, roach, crucian carp, wild carp, and others) l/L varies from 10 to 45* for $\bar{u}_m = 1$, but in the case of small fast marine fishes (mullet, mackerel, Atlantic mackerel, scad, bonito) l/L varies from 2 to 8* for $\bar{u}_m = 1.5$ to 3.0. This is an indication of the hydrodynamic value of scales.

Supported by our histologic studies on shark scales (42), we present the results of a hydrodynamic evaluation of scales according to boundary layer theory (Figure 4). It is evident from the graph that the relative extent of protrusion of a scale k/L lies between the permissible height of the roughness with turbulent and (conditionally) [laminar] flow boundary layers (44), namely, $(k/L)_{\delta}<k/L<(k/L)_{a}$. Accordingly, with an increase in the Reynolds number, the height of the protrusions of the scales comes steadily closer to the minimum permissible values. It is interesting to note that for sharks the relative height of the scale proper is equal to the latter, while the total height (scale plus keel) is at the level of the corresponding values for the scales of bony fishes. Thus, the height of the protrusions of the scales satisfies the demands of boundary layer theory for both bony fishes and sharks.

Another general characteristic of the tendency for scales to change with increase in the Reynolds number is the intensified directive action of scales, as shown by a number of factors. The general longitudinal ribbing of the scales of large fast bony fishes and sharks was mentioned above. It is clearly manifested in the latter by keels (42). One can clearly distinguish on the surface of sharks loc. zones of change in scale and keel orientation to the longitudinal direction of the body at an angle of 10-15° up to 40-45°. These zones are found in gill slits, pectoral, dorsal, and ventral fins, and in the tail. The angles of deviation of keels from the longitudinal direction change with increase in swimming speed of the sharks, and the very fast mako has additional local zones in the anterior part of the body (on the side) and in the tail.

Unlike small slow fishes, a new formation in the form of a pectoral corset appears on the scales of bony fast fishes. It is situated directly behind the gill covers and has a complex contour with an indistinct boundary in the bonito; it is quite pronounced in scaly and scaleless tunas. Some tuna species have a very well-developed corset covering about one-third of the body surface (43). The corseted scales are strong, flexible, and light and occur in bundles with three or four scales in each. They undoubtedly maintain the shape of the anterior part of the body unchanged in fast fishes when exposed to high dynamic water pressure. The very shape of the boundaries is indicative of the directive action of the pectoral corset: it is narrow on the back and abdomen and fairly elongated on the lateral surface of the body. Corseted scales line the region around the pectoral fins. Thus, the conditions for maintaining body of revolution flow around local obstacles are satisfied.

In all sharks, the scales are round, smooth, without keels, and close together in the front of the protruding parts of the body--on the tip of the snout, on the anterior edges of the fins where the boundary layer is known to be laminar, on the dorsal crest, and around the eyes where the flow of water is sometimes oblique. Keels gradually form across several rows of scales, first in the after part of the scales and then in the forward part. The width of the regions with indistinct keels varies from species to species, depending on the size and speed of the shark. The developed keels increase in height from the head to the middle of the fish, i.e., as the boundary layer expands, and then decrease with decrease in cross section of the tail and increase in amplitude of the oscillatory movements.

Thus the hydrodynamic function of fish scales is not determined solely by their roughness, as is often assumed. The scale layer of fast fishes differ significantly from the ordinary rough surface of solid bodies in the following respects: (i) regular checkerboard arrangement of uniform and similar scales in a way that regulates vortex formation in the boundary layer; (ii) smooth contours of scales in cross section to ensure continuous flowing around, e.g., the familiar shape of the cycloid scale; (iii) directive action of microelements in shark scales, including the keels which have a pronounced general longitudinal direction and hydrodynamically sound local regions of change in orientation; (iv) scale flexibility manifested during bending and oscillatory movements of the body; (v) the extent of scale protrusions is in the interval of permissible values according to boundary layer theory; (vi) the scales of fast bony fishes are always covered by epidermis and slime released by the excretory cells. In sharks, a scale with its own plate may pierce the epidermis, but it probably also has a slime coating. Slime is a biopolymer lubricant with the distinct capacity to diffuse in the boundary layer.

The above-mentioned hydrodynamic qualities of scales justify our regarding them as a means of retaining slime on the body surface and as an organ which performs several simultaneous functions directed toward regulating the boundary layer of fast fishes. This conclusion is supported by the following theoretical and experimental considerations based on the presence of a vortex field proper in the scales. There is a theoretical solution (5) which shows that turbulence in a laminar flow with uniformly distributed vorticity quickly subsides if the vortices of the positive and negative directions of rotation are arranged in checkerboard fashion. Such a distribution of vortices over fish scales can indeed exist. Moreover, further analysis of experiments in an aerodynamic tunnel with large solid wave models in a two-dimensional flow with $Re_g = 2 \times 10^6$ (4) revealed the following. With an appropriate wave configuration, the velocity profiles in the boundary layer are transformed favorably for maintaining the stability of the boundary layer both at the crest and in the trough of a wave. This is particularly possible over fish scales where the waves are three-dimensional in character and the spreading of the boundary layer on each scale is assured.

Finally, our experimental data on the microdimensions of shark scales show (Figure 5) that the area S of a scale and the distance λ between the keels of the scale in fast sharks are smaller than in slow fishes and that the absolute values of these quantities steadily decrease with increase in the Reynolds number. However, the relative values of the size of a scale approach some maximum values, i.e., the ratio of the length l to the width c of a scale is $l/c=1$ while the ratio of the distance λ between the keels to the height of their a is $\lambda/d = 2.6$. These ratios are significant because of the stable condition of the boundary layer after the creation of spatial turbulences in the form of longitudinal cellular convective vortices in which the length of a wave of turbulence across the main flow is λ while the depth of the cells is d. It was theoretically found and experimentally confirmed that in case one boundary is free and the other is fixed (as in the cell of a scale), the critical value at which cellular vortices no longer spread to the entire depth of the boundary layer is $\lambda/d = 2.66$ (45). This value is adhered to with striking accuracy in the terminal scales of the fast mako shark.

Fish mucus attracted the attention of investigators some time ago, but it was studied mainly in small slow bony fishes and not in relation to the skin structure and scales. Some investigators denied that it was present in sharks. The general view was that fish mucus has a multifunctional purpose chiefly defensive in nature.

In our own studies on bony fishes and sharks, including large fast species, we studied the various types of secretory, mucus-forming cells of the epidermis, the chemical composition of mucus, the quantitative distribution of secretory cells on the body surface, and change in the factors affecting mucus with increase in the Reynolds number. We determined the chemical composition of secretory cells using Schiff's test with such stains as mercury bichloride-bromphenol blue, thionin, and alcian blue. We devised a special technique for preparing epidermis sections in order to study the topography of secretory cells. We used a special instrument to determine the thickness of the mucus layer on a live fish (21). It involved measuring the distance from an air bubble that settled on the body surface to the stained epidermis. The mucus layer was found to be 40 to 45 micrometers thick on the average with variations from 25 to 60 micrometers, partly due to instrumental error.

Three types of secretory mucus-producing cells can be distinguished in the skin of the various species of fish: cup-shaped, flask-shaped, and granular. They differ from one another with respect to location in the various layers of the epidermis, shape, size, internal structure, and chemical composition.

We found that the production of mucus and the way it is supplied to the body surface depend on the size and swimming speed of the fishes. Small slow-swimming freshwater fishes have two or three types of secretory cells, medium-fast fishes one or two, and fast bony fishes and sharks only one, i.e., granular (3). Thus, with increasing swimming speed, i.e., increase in the Reynolds number, a narrow specialization, as it were, of secretion takes place in the fishes. Depending on the nature of the secretory cells, the mucus synthesized in them reaches the body surface in two ways: by the cells with secretion advancing to the surface of the epidermis where it is completely destroyed and by the mucus coming from the deeper layers of the epidermis via intercellular passages.

The histochemical reactions of the granular secretory cells showed that they contain mucopolysaccharides, nucleic acids, and proteins, i.e., high-molecular polymer compounds. It is generally known that the addition to water of small quantities of high-molecular organic and synthetic polymers of similar composition produces a very effective (about 80%) decrease in the hydrodynamic friction drag of solid bodies moving in solutions of low concentration (11, 35). Thus, fish mucus comes into direct contact with the boundary layer and serves as an active biopolymer coating.

The regular lengthwise distribution of both the number of secretory cells per unit of area and their size in the epidermis in some bony fishes is significant (Figure 5). It is evident that this distribution is related to the body shape and swimming speed of the fishes and to the characteristics of the boundary

layer. Strong turbulence and even separation of the boundary layer may well occur in the places behind the gill slits where streams of water are ejected while the fishes are breathing as well as in the diffusive and very narrow caudal region of the body with its wide amplitude of bending and oscillatory movements. Therefore, fields with high secretory activity are formed here in fast fishes. They contain many of the largest secretory cells (cf. the peaks on the graphs in Figure 5). This is clear evidence of the role played by mucus in stabilizing the boundary layer of fishes. Let us examine now some of the characteristics of different species.

In the small roach, ruffe, white bream, and pickerel which have low Reynolds numbers, the [laminar] flow boundary layer persists along the entire length of the body and the distribution of secretion is uniform everywhere with no peaks. The mucus of these fishes contains two types of secretory cells with different functions. With increasing swimming speed and Reynolds number, the distribution of the secretory cells and the supply of mucus in the epidermis become uneven and only the granular type of secretory cell is found. For example, the pike with its brief quick thrusts has the maximum amount of secretion behind the gill slits; in the caudal region the boundary layer spreads to the large accessory paired fins. Two peaks are characteristic of the distribution of mucus on the fast mackerel in keeping with a body shape that narrows sharply toward the tail (6). The absence of a mucus peak in the bonito is due to both the presence of a pectoral scale corset (for direction control) and the change in respiratory movements.

Unlike slow swimmers, fast fishes are known to have passive respiration: their mouths remain slightly open allowing water to pass freely through the gills. The distribution of mucus in scaly tunas is similar to that in the bonito and their mucus-producing apparatus is particularly well developed in the caudal region. Almost all the epithelial cells are converted here into secretory cells, forming a solid multirow field of mucus-producing cells.

The structure of the secretory apparatus is more complex and specialized in such members of the family Xiphiidae as the sailfish, marlin, and spearfish (20, 48). Their skin contains a mucus-producing system of canals that open onto the body surface through excretory pores. The walls of the canals and pores are covered by multi-layered epithelium with secretory cells, which increases several times the total secretory area and amount of secretion elaborated by the fish. It is important to note that the interconnected mucus-producing canals and excretory pores in the skin of the xiphioid species occur all over the body, including the head. Moreover, two such systems are known to exist, one on the left side of the body and the other on the right side, but they do not communicate with each other anywhere. This suggests that each of the two mucus-producing systems functions alternately during the bending and oscillatory movements of the fish. Thus, the mucus is utilized quite economically.

A powerfully developed secretory apparatus with its specialized hydrodynamic function is found even among xiphioid species in the very fast swordfish whose large individuals have the highest Reynolds numbers of all fishes, about Re_l 1 x 10^8. Even with the naked eye one can see over the entire body and head of an individual 2.6 meters long, pores numbering 0.8 per square millimeter and

0.07 to 0.2 mm in diameter with an average diameter 0.11 mm (on the side of the body). A slimy substance can be easily squeezed from the pores. The pores lead to internal canals that can be exposed by dissecting the upper layers of skin. The canals lie at a depth of one mm parallel to the skin surface and are no more than 1.00 mm (average 0.5 mm) in diameter. Between the intracutaneous mucus cavities are numerous anastomoses, especially in the head and gill covers. The canals on the back and abdomen of the swordfish are intertwined forming an unusual network of these structures, but on the side of the body they are almost parallel to one another and oriented orthogonally by external longitudinal folds and depressions in the skin (18). When a swordfish makes rapid bending and oscillatory movements, the intracutaneous mucus-producing canals on the sides of the body may be stimulated successively from the head to the tail, at which time mucus is released to the boundary layer in small quantities, a very rational method.

We were the first to discover in the swordfish not only the left- and right-side intracutaneous mucus-producing systems common to all xiphioid species but also local mucus-regulating systems found behind the gill slits and along the back, found only in the swordfish. Behind the gill slits are peculiar structures, crypts, whose lining epithelium contains a large number of mucus cells. These structures resemble gastric or intestinal crypts. Swordfish crypts increase secretion behind the gill slits to a greater extent than do those in other and slower fishes whose Reynolds numbers are one-tenth as high.

Along the midline of the swordfish dorsum is a succession of intracutaneous ampullae filled with a slimy substance. They can be found by dissecting dorsal skin at a depth of 10 to 12 mm from the surface in the amount of 2 x 20 units. The maximum length of an ampullae in a fish 2.60 meters long is 30 millimeters and the diameter is about 13 millimeters. The ampullae do not intersect with one another but open into longitudinal excretory slits on the dorsum. The walls of the ampullae and excretory slits are lined with multilayer secretory epithelium while a mucus reserve is present within the ampullae. The lining epithelium has cryptlike processes that intensify the secretory activity of the ampullae. The existence of these ampullae as additional mucus reserves against local turbulence of the boundary layer behind the dorsal fin may be due to the fact that the swordfish fin is very large and thick and is not tucked, even partly, into a special pocket, as in the tuna and the sailfish, when swimming at high speeds. The swordfish deserves special study in the field of bionics by researchers because it possesses unique local mucus-regulating systems in the form of crypts and ampullae.

That the hydrodynamic function of mucus is to lower the resistance of large fast fishes can also be demonstrated by comparing the mucus layer in slow and fast sharks (Figure 7). The Black Sea spiny dogfish is characterized by large secretory cells arranged in a single row evenly over the entire body surface. In the fast Atlantic mako shark, on the other hand, the mucus cells are small and concentrated mostly in the diffusive part of the body where they fill almost the entire mass of epidermis, being arranged in several rows one over the other as in scaly tunas (9). Our detailed studies on the mucus layer in four shark species contradict the view expressed in the literature that these fishes do not have secretory cells.

The researches of other authors who made some additional discoveries also provided direct experimental proof of the value of mucus in lowering hydrodynamic resistance (15, 16, 22, 23, 26, 36, 46). Towing dead pikes in an experimental tank of the gravity type showed that a significant effect with $Re = 1 \times 10^6$ can be achieved only in freshly caught river fish with uninjured skin and intact secretory apparatus. The longer the pike is kept in a tank, the less the effect (like the decrease in effectiveness after the decay of mucus over time (22, 23, 26).

Field experiments with Baykal omuls and graylings in a biohydrodynamic tunnel convincingly showed that the resistance of live fish is less than that of dead ones with an intact mucus layer (26). Experiments with aqueous solutions of mucus from different fishes, including scaly tunas, carried out in a hydrodynamic apparatus with two coaxial cylinders (one of them rotating) confirmed that turbulent friction decreases about 60 percent. At the same time the investigators found the optimum concentrations of solutions of fish mucus that achieve the greatest decrease in resistance. Such optima also exist for synthetic polymers (15, 16).

Of interest are the comparative experimental studies on the decrease in friction resistance in the turbulent flow of aqueous solutions of mucus from freshwater and marine fishes conducted with the aid of a portable rheometer (46). The stainless steel tube of the latter has an internal diameter of 0.58 millimeters and the mucus solution flows through it at the rate of 13.7 m/sec. Solutions from eleven fast marine barracudas 0.66 to 0.79 meters long produced the greatest decrease in resistance (about 66 percent). Barracudas belong to Group I in our hydrodynamic classification (the Wahoo Group--thin-bodied, elongated with an oval head (33)). It is interesting to note that we were unable to achieve a marked decrease in resistance by using a solution of mucus from the "California bonito" and expressed surprise at our failure to do so. The fact is this species belongs to the scaleless tunas, thus confirming our view that there are two groups of tunas differing from each other with respect to the nature of the integuments and the presence of mucus.

Mention should be made of the results of comparative experimental studies on the hydrodynamic resistance of turbulent flow in metal tubes containing suspensions of epidermal cells from Black Sea dolphins (38, 47). Suspensions of cells from the sloughed off layer of epidermis from the bottlenose dolphin and slow harbor porpoise were tested. The concentrations of the suspensions ranged from 0.002 to 1.0 percent, but in all cases the hydrodynamic resistance of the suspensions scarcely differed from that of freshwater under turbulent conditions with identical Reynolds numbers. Thus, these experiments confirmed our contention that there is a qualitative difference in the mechanisms of decrease in hydrodynamic resistance of skin between most fast fishes and dolphins.

There are different experimentally supported theoretical explanations of the mechanism of decrease in resistance of aqueous solutions of fish mucus in low concentrations, which also confirm our views (12-14, 17, 29). The mucus of a swimming fish diffuses into the boundary layer. The concentration of the solution decreases with distance from the skin surface while its viscosity increases

to the viscosity of the solvent-water. Analysis of differential equations of a boundary layer with variable viscosity shows that its presence with a positive gradient is equivalent to a change in the vertical component of velocity and that stabilizes the laminar flow. A combined solution to these equations and the diffusion equation with an investigation of the stability of the given flow to low turbulence in a case involving the flow around a semi-infinite plate revealed the following. When there is an increase in the Prandtl number $Pd = \nu_\infty/d$, where ν_∞ is the viscosity of the fluid of the approach stream and d is the coefficient of diffusion of mucus, the effect of the viscosity gradient is manifested next to the wall. With slight distance from the wall, the profile of the velocities differs little from the ordinary distribution of velocity within the boundary layer. Neutral curves for the boundary layer on a flat plate with an increase in the Prandtl number show a substantial decrease in the region of flow instability and an increase in the critical Reynolds number, e.g., by a factor of 10^4 compared with the case of a boundary layer without a viscosity gradient (Blasius' solution) (12, 29).

Another theoretical explanation of the effectiveness of fish mucus is based on the following two characteristics of the flow of polymer solutions, which were experimentally established and repeatedly confirmed by different investigators.

1. Only solutions of high-molecular polymers with a chain structure and relatively long particles significantly decrease hydrodynamic resistance.

2. Solutions with long particles affect the layer of fluid near the wall and do not cause changes in the zone of the turbulent core of the flow. This suggests that the long particles of the bio-polymers are oriented along the wall of the flow due to the large velocity gradient in the viscous sublayer and transition layer, thus extinguishing the transverse pulsation of the velocity v' and causing trubulent friction ($\rho u'v'$) to decrease. The resulting theoretical correlation links the characteristics of the boundary layer to those of the solution, producing a quantitative evaluation of the estimated effectiveness consistent with the experimental data. For example, with a solution viscosity of $\mu = 2$ cp and a Reynolds number of $Re_x = 10^7$, the gain in flow velocity is doubled.

We should like to note, in conclusion, that in the course of the present study we uncovered many new facts about the structure, functional significance, and interaction between the flow boundary layer and the integuments of various fish species. Our findings will introduce significant changes into our knowledge of these widely distributed inhabitants of the World Ocean who are the major objects of bionics research.

Based on a large mass of experimental material, we were the first to show the following pattern in the integuments of fast fishes which function to reduce hydrodynamic resistance.

With an increase in the Reynolds number to Re_x 1 x 10^6 of both bony and cartilaginous fishes, the multifunctional mucus layer becomes a leading factor influencing the boundary layer. This is due to the divergent development of the skin of fast fishes with especially thick multilayered secretory epithelium and

limited mobility of the subjacent interconnected layers of skin, reduction of the scales, intensification of the directive action of the scales, specialization of the secretory apparatus, and increase in the amount of diffusive active biopolymeric mucus in the skin of the tail of sharks and scaly tunas and all over the surface of xiphioid fish species. The mucus layer of swordfish is particularly outstanding in its hydrodynamic function. We were also the first to discover that the raised mucus-covered surface of its skin has longitudinal folds and depressions, left-side and right-side mucus-producing systems of intracutaneous canals with excretory pores, and sites that regulate the discharges of mucus with branched crypts behind the gill slits and reserve ampullae situated along the dorsum.

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SOME HYDRODYNAMIC PATTERNS IN STRUCTURE OF INTEGUMENT OF MARINE ANIMALS

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[Article by V. B. Babenko and O. D. Nikishova, Institute of Hydromechanics, Ukrainian Academy of Sciences, submitted 23 May 74]

[Text] The swimming speed, as well as morphological structure, of aquatic animals are related to the physical parameters of the environment, mode of propulsion and life style. In turn, the influence of the environment on the integument of aquatic animals depends on speed, conditions and mode of swimming, and it is unrelated to animal species. In the course of evolutionary development, different species of animals developed similar adaptations for rapid swimming. For this reason, it was interesting to relate the physical aspects of processes in the boundary layer with flow around a solid of revolution, which have been studied well and comprehensively, to the properties of the well-innervated integument of marine animals.

To date, there has been little study of the nonstationary nature of propulsion of marine animals. However, it was demonstrated [7, 8, 13] that, in the first approximation, the nonstationary nature of active swimming has an insignificant influence on the nature of flow and general frictional drag. For this reason, we shall use here a quasistationary approach to discussion of this question.

There has been little study of the interaction between flow and the skin of marine animals, which differs from a rigid surface in its mechanical properties. Moreover, the superficial layers of the skin of marine animals are more profusely innervated than human skin [18]. Let us make a hydrodynamic analysis of the morphological structure of the integument of marine animals. Let us consider the flow of water around the body of marine animals on the example of the dolphin, on the assumption that its body is rigid. Let us then determine which hydrodynamic characteristics of flow could serve as a stimulus for the skin and in which direction the animal's adaptation should have proceeded to eliminate undesirable exogenous stimuli. We shall draw upon existing morphological and hydrodynamic data to prove expounded hypotheses.

In the streamline boundary layer, the asymptotic increase in thickness of which along the body is attributable to the correlation between viscous and inertial forces of the incident flow, exchange of kinetic energy between basic and exciting [perturbing] motion in the region of the critical layer. It may be considered that the coordinates of location of the critical layer coincide with the coordinates of displacement thickness δ^*. Figure 1 illustrates a solid of rotation which approximates the external outline of a dolphin. Line 4 refers to the value of δ^*, which was calculated in [2].

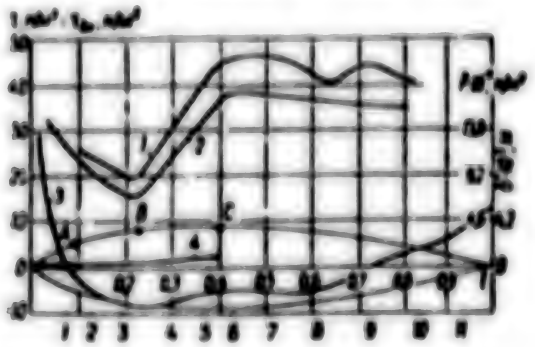

Figure 1.
Distribution of hydrodynamic characteristics along solid of rotation similar in shape to body of a dolphin
1) tangential (shearing) stresses on internal skin surface
2) tangential stresses
3) static pressure
4) displacement thickness of laminar boundary layer

Negligible fluctuations of longitudinal velocity of the main flow will cause substantial change in shape of the streamline in the nose of the model (in the region of maximum curvature of displacement thickness). This could provide conditions for appearance of Tollmin-Schlichting waves, even if all other body streamline conditions are ideal. Then, one of the means of increasing the length of the laminar and transitional segments of the boundary layer and reducing the frequency spectrum of pulsating velocities is to obtain a smoother, close to linear, increase in thickness of laminary and turbulent boundary layers, i.e., "linearization" of increase in δ.

Since the thickness of the boundary layer is determined by changes in correlation between viscous and inertial forces, the most reliable means of affecting it may be interaction between elastic-damping integument or mucous surfaces of the body and incident flow. The zone of maximum gradients of curvature of thickness of the boundary layer is small, and therefore the "linearization" method should be quite effective over short distances.

For this reason, the sword of some swift fish may also be considered as a means of "linearization." In this case, the turbulent boundary layer appears on the sword, and for this reason we observe virtually linear increase in thickness of the boundary layer, while the negative pressure gradient in the anterior part reduces the frequency spectrum of velocity pulsations. Thus, the need for "linearization" of increase in thickness of the boundary layer in marine animals is an indirect reaction of their receptor system to other stimuli, and it may arise to reduce friction drag and the frequency range of pressure pulsations.

It may be assumed that the gradient of curvature of δ^* is the first factor affecting the receptor system of marine animals. The pattern of distribution of static pressure $\bar{P}$ along the body may be the second factor. The distribution of $\bar{P}$ calculated in [12] is illustrated in Figure 1, curve 3. It is known that the Reynolds number of transition on solids of rotation is in the vicinity of minimum value of $\bar{P}$. Thus, the shape of a rigid body influences the length of the laminar and turbulent boundary layers.

A change in sign of the pressure gradient and parameter $\bar{P}$ itself, observed in the region of minimal pressure, are a direct stimulus of the receptor system. The Reynolds transition number can change because of the shape of the body, mode of propulsion and influence of stabilizing properties of the integument on the boundary layer. For this reason, the animal's reaction to the stimulation of the second factor should have been manifested, as a result of lengthy evolution, by a change in the above stimuli in the required direction.

Indeed, the shape of the dolphin body is laminary. The rigid laminary profiles used in engineering reduce resistance to 30%, $Re = 5 \cdot 10^8$. Dolphins can alter the shape of their body when swimming at different speeds [6] and increase the efficacy of effect of laminated shape on reduction of resistance. Redistribution of $\bar{P}$ along the delphinid body is observed as a result of mode of propulsion [13, 14]. It has been demonstrated [6] that there is a readjustment of stabilizing properties of the delphinid integument at maximum swimming speeds.

Thus, when taking measurements on marine animals, one should find a more even distribution of $\bar{P}$ in the region of the change in sign of pressure, and the pattern of distribution of $\bar{P}$ along the body should differ from that illustrated in Figure 1, Reynolds transition number should be higher than that of a rigid solid, and marine animals should be able to shift the zone of transition from laminary to turbulent boundary layer by means of reflexes.

The distribution of pressure along the body has another functional meaning. We see in Figure 1 that most of the body is under the influence of stimulation. In spite of the significant hydrostatic pressure, particularly when diving, most of the integument is, so to speak, separated from the skeleton of the body. This explains the appearance in dolphins of a skin muscle and specific skin structure, which counteract separation stress. Analogous adaptations are present in the integument of other marine animals. The skin muscle of delphinids and its receptor system are subject to variable stress depending on swimming speed and depth. To eliminate this stimulus, the delphinid adaptations should be directed toward displacement of the zone of stimulation closer to the caudal part of the body that is subject to dynamic stress with the oscillatory mode of propulsion.

The third stimulating factor could be the distribution of tangential stresses τ along the body (see Figure 1, curve 2). Point A shows the coordinate of location of Reynolds number for buckling ["loss of stability"], Re_b, determined by the calculation method in [15] for solids. Point B refers to the Reynolds transition number, or bottom critical Reynolds number, Re_{cr_1}. Its coordinate is found in the region of minimal pressure. Point C characterizes the start of developed turbulent flow and is determined from the ratio for solids of rotation, $x_1/x_2 = 1.6$, where x_1 is the longitudinal coordinate of Re_{cr_1} and x_2 is the corresponding coordinate of the top critical Reynolds number, Re_{cr_2}.

Curve 1 refers to the tangential stress on the internal boundary of the integument τ_{in} induced by tangential stresses τ. The thickness of the skin was determined on the basis of [4]. For our calculations we used 1.0 m as the length of the body and 7 m/s as velocity of propulsion. For point A, we found that $x = 0.176$ m and $Re_b = 1.2 \cdot 10^6$; for point B the figures were $x = 0.43$ m and $Re_{cr_1} = 3.3 \cdot 10^6$, and for point C $x = 0.76$ m and $Re_{cr_2} = 5.2 \cdot 10^6$. As can be seen from curves 1 and 2, a sharp change in magnitude of τ_{in} in the transitional region of the laminar boundary layer and in the region of the top and bottom critical Reynolds numbers may be a direct stimulus for the receptor system of the integument of marine animals.

The length of the transitional zone and its location along the body may fluctuate substantially, depending on swimming velocity and other factors. We know from experiments with synthetic damping surfaces that the values of the above-mentioned Reynolds numbers may change over a wide range. For example, it was possible to double the value of Re_b by means of a damping surface [3, 17].

Thus, the animal's reaction to a stimulus referable to the third factor should be directed toward enlargement of the transitional zone in the boundary layer and achievement of more even and rectilinear patterns, as shown by curves 1 and 2. The value of τ_{in} depends on the distribution of skin thickness along the body and correlation between local skin thickness and diameter of the body. By altering these parameters marine animals can actively counteract stimuli referable to the third factor. But if this is not advantageous from the standpoint of energy, it is purposeful to shift the transitional zone to the region of the sword, as is the case in the swordfish, to avoid drastic or sign-changing gradients of tangential stress along the body. The presence of a more rigid integument in the nasal part of the body of some swift-swimming fish may be viewed as an adaptation to stimuli of the third type.

It must be stressed that there is a difference between the second and third factors, consisting of the fact that the stress on the skin will be of the separation type in the former case and shear type in the latter.

The fourth factor, which affects the receptor system of the integument in the form of pulsations of velocity and pressure in the boundary layer, is notable for its dynamic mode of stress. When considering this factor, it is important to bear in mind not only the magnitude, but frequency spectrum of pressure pulsations. Figure 2 illustrates the curves of the spectrum of force of pressure pulsations in different places along a rigid plate, with flow-around velocity U_∞ = 5 m/s, calculated using the following formula, which was taken from [11]:

$$S_p(\omega) = \frac{\text{[illegible]}}{\text{[illegible]}}$$

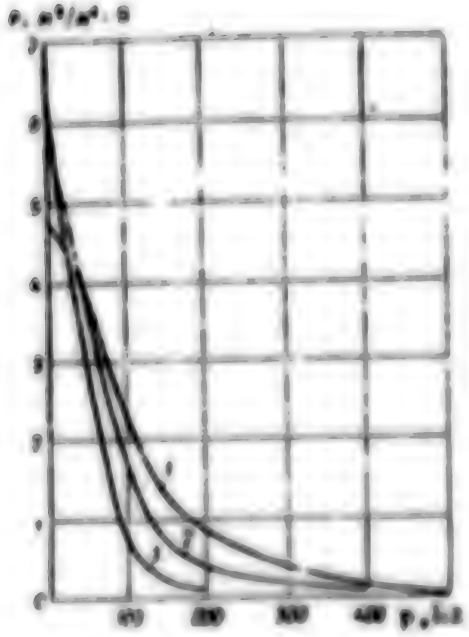

Figure 2.
Spectra of force of pressure pulsations for rigid plate with different values of x:
1) 0.8 m 2) 1.4 m 3) 2.0 m

We see from this figure that low frequencies carry the most power.

Figure 3 illustrates the regions of unstable fluctuations when there is a laminary boundary layer around the rigid and elastic-damping plates [3, 17], as compared to a region of turbulent pressure pulsations on a rigid plate. The extreme neutral curves 1 and 2 are indicative of the presence of oscillations that do not grow as a function of time at the given rate of exciting motion [3, 17]. We see that with flow around a rigid plate there is an analogous pattern of oscillations in both the laminar and turbulent boundary layers. In the regions of buckling and start of fully turbulent flow there is a maximum range of frequency fluctuations. The frequency range narrows down appreciably between these typical zones and further on, along the plates. (The force spectra were calculated with consideration of 95% of the complete range of frequencies).

The data illustrated in Figure 3 are very difficult to estimate for a solid of rotation at the present time. For this reason, the velocity was reduced (points A and C in Figure 3 correspond to points A and C in Figure 1) on the plate for better approximation to a body of rotation.

The opinion is held that marine animals can sense pressure pulsations and deliberately alter the properties of their integument to reduce such pulsations, thereby lowering friction drag.

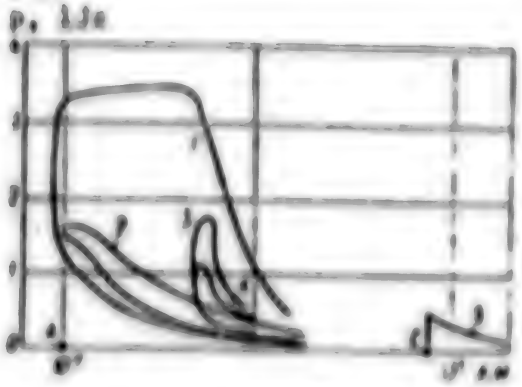

Figure 3.
Neutral (2, 4) and extreme neutral (1, 3) curves for laminar boundary layer and force spectra (5) of pressure pulsations in turbulent boundary layer with U = 5 m/s
1, 2) for ridig plate
3, 4) for damping plate

There are no data yet concerning sensitivity of the dolphin's skin to pressure pulsations, but it has been indicated that the density of nerve endings is denser near the surface of delphinid skin than in man [16]. If we assume that the tactile sensibility threshold of the dolphin's skin is not higher than maximum sensibility of man, pressure pulsations in the turbulent boundary layer are on the boundary of sensibility at cruising speeds of swimming. In the transitional zone, the amplitude of pressure pulsations is 2-5 times greater than in a fully developed turbulent layer [9]. Since reception of pressure occurs only at the site of a pressure gradient, the alternation that exists in the transitional sector should be well perceived by the animal's skin. It has been demonstrated [12] that the density of nerve endings in the skin section between sections ϕ and β (Figure 4) is somewhat lower than on the head and tail. Perhaps this is related to the fact that expressly here a transitional mode of flow is established, with marked pressure pulsations and alternation. It is also interesting [4] that there is appreciable thinning of subcutaneous fatty tissue between sections ϕ and β (see Figure 4b), which is consistent with experimental studies of the distribution of cutaneous elasticity in dolphins [5] and indicates that this segment of the skin is capable of interacting actively with flow in the boundary layer.

Indeed, while the region of transitional flow is situated between sections δ and ϵ in a solid, this zone is shifted in dolphins to the caudal part of the body back to the flukes [propelling device]. Estimates have shown that when swimming at cruising speeds a close to streamline [laminar] flow in the boundary layer should be maintained over 70-80% of the dolphin body surface [3, 10].

The reaction to stimuli of the fourth type may consist of reduction of power and frequency spectrum of pulsations of velocity and pressure, as well as of gradients of oscillation spectra, which is also observed both in synthetic damping surfaces (see Figure 3, curve ϕ) and experiments with dolphins [8, 13], and achievement of more uniform distribution along the body of the oscillation frequency spectrum.

After comparing the submitted data to the structural distinctions of marine animals, it may be assumed that the principle of high receptor

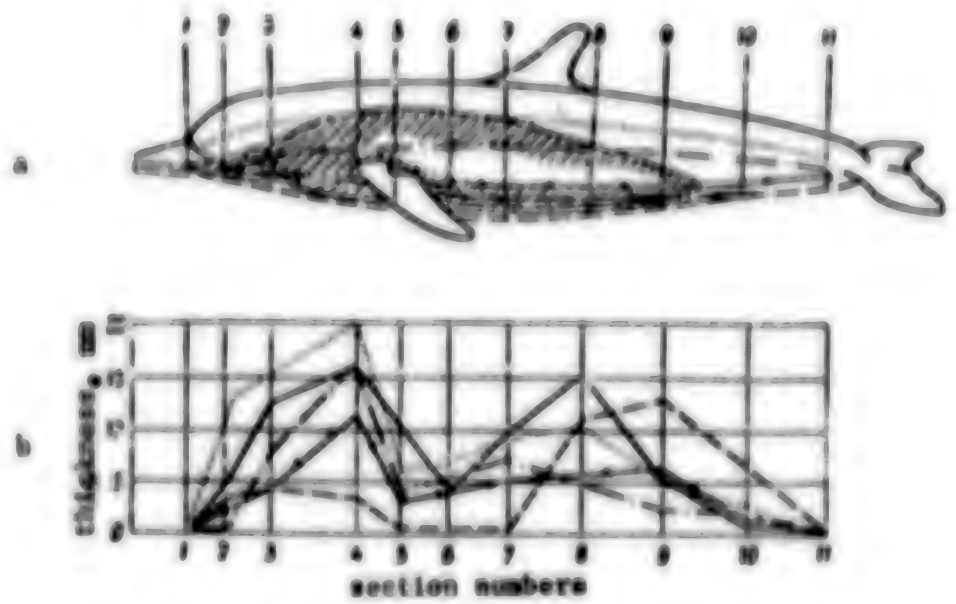

Figure 4. Diagram of location of cutaneous muscle (a) and patterns of distribution of subcutaneous fatty tissue (b) along dolphin's body

sensibility of the integument of rapidly swimming objects exists in nature as a factor of natural selection, which determins the structural patterns of their integument.

Let us mention the general features of the factors discussed, which affect the receptor system of marine animals: the factors are interrelated and their effects are complex; they are characterized by maximum gradients of their magnitudes in the zone of maximum influence; the level and zone of influence of the factors are related to the velocity and mode of propulsion; the effects of the factors are related to the velocity and mode of propulsion; the effect of the factors is essentially integral, zonal, but it may be combined with a dynamic local influence.

We have discussed the hydrodynamic distinctions of flow of liquid near a rigid solid of rotation similar in shape to the body of a dolphin. As a result of lengthy evolution, marine animals developed adaptations under the influence of the above-mentioned factors, which enable them to successfully counteract exogenous stimuli. For this reason, under actual conditions, when moving at a high speed the characteristics of flow along the elastic-damping surface of marine animals will differ from analogous ones in the case of flow around a rigid body, and this has already been experimentally confirmed in part. In analyzing interaction

between flow and the integument of marine animals, it is also important to take into consideration the physical distinctions of structure of flow of liquid in the region of transition from streamline to turbulent boundary layer along the elastic-damping boundary.

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CORRELATION OF HYDRODYNAMIC FUNCTIONS OF CYCLOID AND CTENOID SCALES IN FISH

Moscow ZOOLOGICHESKIY ZHURNAL in Russian No 6, 1970 pp 869-871

[Article by V.D. Burdak, Institute of Biology of the Southern Seas, Ukrainian SSR Academy of Science, Sevastopol']

[Text] Investigations have shown the regressive development of the ctenoid apparatus in the ontogenesis of the gray mullet (Mugil cephalus L) given a Reynold's number of $Re > 5.0 \cdot 10^6$. This value is related to a decrease and elimination of laminar function which is part of ctenoid apparatus activity. Analysis of the hydrodynamic function of the cycloid and ctenoid scales shows that the existence of these type of scales can be viewed as segmental changes in stages of adaptation to a decrease in hydrodynamic resistance.

One of the significant aspects of adaptation of fish to a decrease in hydrodynamic resistance has been the development of a specialized function of their skin covering which guarantees the regulation of the boundary layers (Walters, 1962; Aleyev, 1963; Kudryashov and Barsukov, 1967, 1967a; Burdak, 1968, 1969, 1969a). One of the adaptations of this type is the existence of the ctenoid apparatus in fish. We recently evaluated in greater detail the hydrodynamic function of this structure (Burdak, 1968, 1969, 1969a). The results of these studies indicate that the ctenoid apparatus is an effective means of regulating the boundary layers and, given a specific Reynold's number, acts as a lamina which decreases the degree of turbulance in the boundary layers.

These theoretical premises point to the fact that with an increase in the Reynold's number, the ctenoid apparatus must lose its hydrodynamic significance (Burdak, 1968). Further investigation indicates that, given a Reynold's number of approximately $3.5 \cdot 10^6$, during the ontogenesis of the large

gray mullet, in particular the striped mullet (Mugil cephalus L.), the ctenoid apparatus actually begins to develop regressively. However, in the striped mullet when the length of the fish is approximately 70 cm which corresponds to a Reynold's number of about $5.0 \cdot 10^6$, this regressive development completes the destruction of the ctenoids. Thus, adaptation related to a defined course in the boundary layer is determined by the size of the Reynold's number.

This process of ctenoid destruction proceeds in two directions. First of all, a gradual falling away of ctenoids throughout the detached area of scales occurs which leads to thinning of the linear web and degradation of its functional ability. Secondly, the character of the whole batch of new ctenoids is changed with each new formation of scale layers. In the period of progressive development of the ctenoid apparatus, the ctenoids are arranged in borders in strictly defined positions and have more or less the same form and dimensions. These scales are distributed in the detached area of the scales in correctly alternating order according to their hydrodynamic function (see figure 1). In a period of destruction of the ctenoid apparatus, the distribution of the ctenoids becomes more disordered and their form and dimensions more varied. Along with correctly arranged ctenoids deformed scales, curved ones without ridges and scales with rounded peaks etc. appear more frequently (see figure 2). Furthermore, separate cycloid sections on the border areas appear, ctenoids become more rare and finally, practically no ctenoids appear in each sequence of scale layers--the scales become cycloid daily. Furthermore, the scales remain only weakly sinuous, not at all like the ctenoids (see figure 3).

Thus, in ontogenesis a number of obvious stages of development of the skin layers can be differentiated: 1) scaleless, 2) primary cycloid, 3) ctenoid, 4) secondary cycloid.

In the gray mullet, the first stage (scaleless) begins at the moment of hatching from roe and ends when the fish grows to a length of approximately 1 cm and has a Reynold's number of $2.0 \cdot 10^5$. This stage conforms to a state of plankton larvae and the earliest young fish.

The second (primary cycloid)stage is prolonged until the moment when the surface area of the body, covered with ctenoid scales begins to exceed the surface area covered with cycloid scales. In gray mullet this occurs when it reaches a length of approximately 5.0 cm and has a Reynold's number of approximately 10^5. From the functional stand point this stage corresponds to

swimming in subcritical courses of direction where the threat of turbulization of the boundary layer has not occurred.

The third (ctenoid) stage lasts until a large part of the body surface remains covered with ctenoid scales, usually up until the fish obtains its full length of about 70 cm which corresponds to a Reynold's number of about $5.0 \cdot 10^6$. Functionally, this stage reaches that Reynold's number when it is possible to effectively diminish turbulence with the help of the ctenoid apparatus; that is, when adaptation is still based on a decrease in the degree of turbulence of the boundary layer.

The fourth (secondary cycloid) stage begins at the time when a large portion of the body surface again appears to be covered with cycloid scales. This stage continues until the end of ontogenesis. This stage corresponds to a state when the ctenoid apparatus can not effectively reduce the degree of turbulence. In these conditions, other adaptive measures directed at decreasing resistance activate.

Our analysis of the hydrodynamic function of ctenoid scales (Burdak,1968, 1969, 1969a), together with other studies suggest certain general aspects of the relationship of hydrodynamic function of cycloid and ctenoid scales in fish. Viewed as a whole, cycloid and ctenoid scales represent two stages of development of one and the same type of adaptation. In both phylogenesis and in ontogenesis, the scales are altered in relationship to changes in the directional course. In turn, the Reynold's number is altered. In relation to these facts, cycloid and ctenoid scales should be considered not as individual types such as placoid, cosmoid and ganoid types, but as subtypes of elasmoid scales (L. Bertin, 1944, 1958). He defined the elasmoid type of scale on the basis of the exact morphologic moment. Bertin's classification and our studies showed the functional nature of cycloid and ctenoid scales.

Four basic types of scales can be identified: placoid, cosmoid, ganoid and elasmoid. This classification, to a large degree, defines the morphologic and functional specifications of different types of scales.

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SCALE TYPES AS STAGES IN THE HISTORICAL DEVELOPMENT OF THE HYDRODYNAMIC FUNCTION OF FISH SKIN

Moscow ZOOLOGICHESKIY ZHURNAL in Russian No 8, 1973 pp 1208-1213

[Article by V. D. Burdak of the Institute for the Biology of the Southern Seas under the Ukrainian Academy of Sciences, Sevastopol': "Scale Types as Stages in the Historical Development of the Hydrodynamic Function of Fish Skin"]

[Text] On the basis of original data, an examination has been made of the hydrodynamic function of the placoid, cosmoid, ganoid and elasmoid scales of fishes. Various types of scales have been examined as stages in the development of the hydrodynamic function of the skin in nectonic fish-like forms and fishes. It is shown that the protective function of the skin ossification in phylogenesis has been replaced by the hydrodynamic function which consists in reducing the degree of turbulent pulsations in the boundary layer.

The adaptation of fish-like forms and fish to a nectonic way of life has presupposed as a whole the progressive development of all adaptations related to active forward motion. One of the aspects of this process has been the regular change of the skins in the various taxonomic groups of fish-like forms and fishes, and aimed at strengthening and complicating the hydrodynamic function of the skin. Individual types of scales such as placoid, cosmoid, ganoid and elasmoid, in this sense represent definite stages in the development of one or another adaptation, and this is examined below.

The basic trend in the evolutionary development of skins of nectonic fish-like forms and fishes consists in a gradual weakening of the protective function of these skins with a simultaneous strengthening of their hydrodynamic function. From the heavy massive armor of the nectobenthic Agnatha (Thelodonti, Heterostraci, Osteostraci and others) and the primitive nectobenthic fishes (Antiarchi and others) in which the ossification of the skin undoubtedly played exclusively or almost exclusively a protective function, evolution led to the nectonic Actinopterygii with a delicate elasmoid

scale having only a hydrodynamic function and being virtually completely devoid of a protective function. As was already noted previously (Kudryashov and Barsukov, 1967), in essence there are no conclusive arguments in favor of the existence of a protective function in the cycloid and ctenoid scale.

The material for carrying out the given work was the scales of various fishes collected by the author at different times in the Black Sea and in the inland waters of the USSR. The placoid scale was examined from the example of the Black Sea shark *Squalus acanthias L.* with the use of data in the literature (Bigelow and Schroeder, 1948), and for other shark species. The cosmoid scale was studied in *Neoceratodus forsteri* (Krefft), *Protopterus aethiopicus* Heckel and *Lepidosiren paradoxa* Fitz; the ganoid scale in *Polypterus senegalensis* Cuv., *P. bichir* Goffr., *Calamoichthys calabaricus* Smith and *Lepisosteus osseus* (L.). All the materials on *Neoceratodus*, *Protopterus*, *Lepidosiren*, *Polypterus*, *Calamoichthys* and *Lepisosteus* were obtained at the Zoological Museum of Moscow University with the assistance of A. A. Svetovidova and at the Zoological Institute of the USSR Academy of Sciences with the aid of V. V. Barsukov. To them the author would like to use this occasion to express his gratitude. The materials on the elasmoid scale were examined in previously published works by the author (Burdak, 1968, 1969, 1969a, 1969b, 1970, 1972).

The first indisputable evidence of the presence of a hydrodynamic function in the scales is found in the earliest known fish-like forms, the Thelodonti, the placoid scale of which had longitudinal ridges (Obruchev, 1964) which inevitably carried out, according to their structure, the functions of laminarizer elements (Burdak, 1968). It is interesting that the ridged scales belonging to the representatives of the Thelodonti and dating back to the Ordovician from the surroundings of Leningrad are the oldest remains of vertebrates which are presently known.

Longitudinal plication is found on the armor of many nectobenthic Agnatha (Heterostraci, Osteostraci) and primitive nectobenthic fishes (Antiarchi) (Obruchev, 1964a). These plicas, judging from their morphology, also fulfilled a function of laminarizer elements, contributing to the more ordered longitudinal direction of the passing flow.

Obviously, both the primitive placoid scale of the type observed in the Thelodonti as well as the reliefs on the armor and individual tesserae of the nectobenthic Agnatha and primitive fishes could carry out only a very limited hydrodynamic function. This is seen from the morphology of all these formations (Obruchev, 1964, 1964a) and, above all, from their slight relief in comparison with that of the developed biohydrodynamic elements in the relief of the scales of fast eunectonic fishes (Burdak, 1968, 1972 and so forth). Such a situation conforms to the relatively low mobility of the designated Agnatha and primitive nectobenthic fishes. As the reliefs found on them on the various skin ossifications represent still to a significant degree the simple result of definite growth patterns of these formations (for example, the concentric reliefs on the tesserae and armor), and, possibly, have not so much a hydrodynamic as a cryptic function the

presence of which is obvious, in particular, for the surface reliefs of the armors in all the nectobenthic Heterostraci, Osteostraci and Antiarchi. At the same time certain facts unambiguously point to the fact that such reliefs on the ossifications of a dermoskeleton in the designated animals at least in certain instances clearly had a hydrodynamic importance as well. Thus, for example in the Thelodonti on the head the scales are smooth, but toward the tail they become elongated and pointed and have small ridges (Obruchev, 1964). The presence of ridges on a scale which covers the diffusor area of the body points to the performing of the functions of a diffusor grid by these ridges, as is observed in many modern fishes in which the elements of the laminarizer are distributed completely identically on the body surface (Burdak, 1968 and so forth).

The gradual strengthening of the hydrodynamic function on the surface reliefs of the skin ossifications, in comparison with the designated reliefs on the scale and armor of Agnatha and Placodermi, can be seen in the examples of the cosmoid and ganoid scales as well as the placoid scales with the more developed longitudinal relief on the surface of the crown.

The cosmoid and ganoid scales still fully maintain their protective significance. This can be seen primarily from the great thickness and strength of this type of scale, as well as their extremely firm attachment to the body of the fish and which the author was able to convince himself of in removing scales from *Neoceratodus*, *Protopterus*, *Lepidosiren*, *Polypterus*, *Calamoichthys* and *Lepisosteus*. In the case of the cosmoid scale, the strength of attachment to a significant degree is explained by the large area of its foot by which it concresces with the connective tissue elements of the skin, and in comparison with the area of the free scale surface which is the point of applying external forces endeavoring to move the scale. The classic example in this regard is, for example, the scale of *Neoceratodus* in which the area of the exposed part of the scale is just 16 percent of the total scale area, while for example in *Clupea harengus harengus* L., this is 37 percent. The great strength of the armor plating formed by the cosmoid scale is also explained by the close spacing of the scales on one another. Thus, in the *Neoceratodus* and *Protopterus* which were examined by us, due to this a protective layer is formed which at each point of the body consists of four-five scale layers.

In *Polypterus*, *Calamoichthys* and *Lepisosteus*, the scales are placed in straight diagonal rows, forming a sort of solid armor consisting of oblique, flexibly connected rings.

The hydrodynamic function of the cosmoid and ganoid scale can be expressed to a varying degree depending upon the morphological features of the scale. In the instance when the scale surface is smooth, for example, in *Polypterus*, *Calamoichthys* and *Lepisosteus*, the hydrodynamic function of the scalation is limited to providing a certain smoothness of the body surface. But in those instances when the exposed surface of the scale has a definite relief, the scale fulfills a more complicated hydrodynamic function consisting, in addition, in the active control of the boundary layer.

Thus, the relief of longitudinal ridges on a cosmoid scale of *Latimeria* (Millot et Anthony, 1958) and in many extinct Sarcopterygii (Vorob'yeva and Obruchev, 1964) obviously was formed as a special adaptation reducing the turbulent pulsations in the boundary layer, that is, performing the function of a complex of ctenoid-like structures and drain troughs on the elasmoid scale of Actinopterygii (Burdak, 1972). An analogous hydrodynamic function is also indisputable in the relief of the longitudinal ridges on the ganoid scale of Palaeoniscі. The morphology of this relief (Berg, et al, 1964) as a whole is also close to the morphology of the ctenoid complex of the elasmoid scale (Burdak, 1972).

Among the fishes examined by us with a cosmoid scale, a special relief which performs a hydrodynamic function is found on the scale of *Neoceratodus*, and this corresponds to its more mobile way of life in comparison with *Protopterus* and *Lepidosiren*.

On the cosmoid scale of *Protopterus*, the surface relief is represented by uniform conical spines which cover the entire covered portion of the scale. This relief clearly does not have hydrodynamic importance and possibly is related to providing a certain physicochemical condition for the skin when the fish is in a cocoon in a state of hybernation. The loose contact of the scales caused by the presence of small teeth on their upper surfaces can help to maintain a layer of mucous between the scales, and this can be of important significance for stabilizing the water exchange of the organism. The exposed portion of the *Protopterus* scale is covered with a thick epithelium and is devoid of any regular relief which would perform a hydrodynamic function.

The cosmoid scale of *Lepidosiren* is completely devoid of a hydrodynamic function, as the scale is small and completely concealed in the skin.

In *Neoceratodus* on the exposed portion of the scale there is a well expressed longitudinal relief of relatively large and tall blunted ridges and alveolae in the middle of the scale and a finer relief of longitudinal furrows closer to the edge. This relief, judging from its depth and even longitudinal direction, clearly performs a hydrodynamic function, representing a developed complex of drain troughs contributing to the dividing of the boundary layer into individual jets.

The placoid scale with a more developed corona having longitudinal crests is predominantly, if not exclusively, an adaptation for controlling the boundary layer and aimed at reducing the turbulent pulsations in it. In this regard, the separating and broadening of the corona of the placoid scale must be viewed as the progressive development of its hydrodynamic function, since an increase in the number of longitudinal keels on the corona is a method for increasing the frequency of the laminarizer elements, and corresponds to more rapid motion. The relief formed on the fish body surface by the aggregate of developed placoid scales looks like a solid field of longitudinally oriented keels and which best contribute to the maintaining of the longitudinal flow in the boundary layer.

In individual groups of sharks, the degree of development in the corona of the placoid scale as a whole is related by a direct dependence with the mobility of the individual species. In slow-swimming forms we usually see the corona in the form of one bent-back conical placoid scale (*Echinorhinus*, *Cetorhinus*, *Centrosciliym* and others), or a slightly broadened corona with one longitudinal crest (*Pseudotriakis*, *Triakis*, *Semiosus*). In the more mobile benthonectonic and eunectonic species, one observes a broadening of the corona usually accompanied by the greater development and increase in the number of crests on it (*Mustelus*, *Squalus*, *Prionace* and others). The greatest width of the corona and the largest number of crests found on it are characteristic for the placoid scale of the large, fast-swimming eunectonic sharks (*Carcharhinus*, *Sphyrna* and others), in which the number of crests on the corona can reach up to five-six.

The greatest development of the hydrodynamic function of scalation is observed in the case of the placoid scale with the most developed corona such as in *Sphyrna*, *Carcharhinus* and other similar sharks, and in the case of the elasmoid scale of Actinopterygii (Burdak, 1972). In both these cases, the scale is virtually completely devoid of a protective function, and performs exclusively a hydrodynamic function, in reducing frictional drag. Consequently, the concluding step in the development of the hydrodynamic function of a scale in the group Chondrichthyes was the appearance of a placoid scale with a well differentiated corona having distinct longitudinal ridges, and in the group Osteichthyes, the appearance of a delicate elasmoid (that is, cycloid or ctenoid) scale which performed different hydrodynamic functions.

Thus, the evolution of the nectonic fish-like forms and fishes ultimately led to the complete elimination of the protective function of the scale and to the maximum development of its hydrodynamic function. The most perfect nectonic forms of fishes both in the group Chondrichthyes and in the group Osteichthyes are characterized by the maximum development of the hydrodynamic function of scalation and by the complete loss of its protective function. This corresponds to the general trend in the historical development of fishes as nectonic vertebrates.

Thus, in analyzing the development of scalation in the phylogenesis of fishes, we are convinced that the various types of scales in fish-like forms and fishes correspond to various stages in the adaptation of these animals to a nectonic way of life.

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CLASSIFICATION OF EQUIPMENT FOR CULTURING MICROORGANISMS

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[Article by L. N. Zaporozhtsev, Sh. O. Arzumanyan and V. N. Serov, Moscow Scientific Research Institute of Vaccines and Sera imeni Mechnikov, submitted 23 Apr 79]

[Text] In recent times, equipment for culturing microorganisms, outfitted with instruments for measurements, recording and automatic regulation of the main technological parameters of the culturing process, has found application in both research and industry. As a rule such equipment consists of two main parts: apparatus ["cultivator"] equipped with devices to stir media and quench foam, systems for aeration and heat stabilization of media, etc., and a measuring unit connected to it, in which are concentrated monitoring and measuring instruments.

We have made an attempt here to classify the series produced equipment for cultivation of microorganisms, on the basis of available literature sources, and this could be of practical value in the following instances: selection of strategy and tactics of scientific research; planning industrial production of biomass with consideration of productivity, quality and homogeneity of product; for development of technological systems of industrial production of biomedical or other products, based on cultivation of microorganisms; development and design of new models of such equipment.

Such equipment can be divided into four groups (see Table) according to instruments furnished and degree of automation of the technological process in equipment presently in series production.

The first group refers to installations that are simple in design and operation [1-4], outfitted only with systems of heat stabilization, mixing and aeration of the medium. Thus, the Poliferm model 1607 has an apparatus consisting of a glass jar and acid-resistant steel lid attached to the jar with a neoprene liner and clamps. The jar is equipped with a magnetic mixer and removable blades. There are openings in the lid for

air to pass in and out, to introduce the culture, and two openings for sensors. The magnetic mixer rotation rate can be set at 100 to 2000 r/min with accuracy of 5%. The temperature is regulated by means of a thermostatic tray to which the jar is attached, and the range is 20 to 60°C with accuracy to ±1°C, provided that the working temperature is higher than the ambient temperature by 7°C or more. The medium is aerated by means of a diaphragm pump with an output of up to 50 l/h. The model is compact and inexpensive; it is used, in particular, in the teaching process.

In equipment referable to the second group [6], the main technological parameters of the cultivation process are measured and recorded. Model M7-N is a typical example thereof; it consists of 5 and 7-l containers made of cylindrical superhard glass with a lid of stainless steel. There are openings in the lid for air to pass in and out, to introduce cultures, collect samples, thermometer and thermal resistance [thermistor], electrodes for measurement of pH and pO_2. There is a top drive on the mixer shaft and it is equipped with two blades, as well as a foam-quenching blade. Mixing rate can be set at 200 to 800 r/min. The system for regulating temperature (in the range of 5 to 50°C with precision of ±0.5°C) includes a pump to circulate water and an electric heater. Air delivery for aeration is measured with a rotameter with a needle valve, and it constitutes 0.5-5 l/min. The control console has a 3-point automatic recorder to record temperature, pH and pO_2.

The third group of equipment [5, 6] is characterized by the fact that during its operation the main technological parameters are measured, recorded and automatically regulated. This type of installation includes ANKUM-2m and Ultroferm model 1601.

The Soviet installation, ANKUM-2m [5], is manufactured upon individual orders, and it is designed for continuous controlled cultivation of nonpathogenic aerobic microorganisms. Continuous cultivation can be conducted in chemostatic and turbidistatic modes, implemented by a system of automatic control of the rate of delivery of nutrient medium and possibility of altering its composition. The installation is constructed on the basis of the modular unit principle, so that instruments can be added to it as a microbiological experiment becomes more complex, and there is interchangeability of units without disrupting the operating modes. The apparatus has a capacity of 3 or 10 l. The passage of air through it is regulated in the range of 0.1 to 10 l/min. The rate of rotation of the mixer is regulated in the range of 200-1500 r/min. Temperature is measured and adjusted in the range of 20-60°C with an accuracy of ±0.5°C. The range of measurement of pH is from 0 to 10, Eh from -200 to 800 mV, pO_2 from 0 to 300% saturation and optical density from 0 to 2.2 units. There is automatic regulation of pH, pO_2 and optical density over most of the range of measurements. There are six channels for dispensing components of nutrient medium into the apparatus. The volume of components of the nutrient medium is regulated in the range of 0.06-2.5 l/h. This apparatus has a 12-point automatic recorder.

Classification of current models of fermentation equipment

Country	Manufacturer	Group 1: equipped with systems of heat stabilization, mixing and aeration of medium	Group 2: main technological parameters are measured and recorded	Group 3: main technological parameters are measured, recorded and regulated	Group 4: computers used to control the technological process
USSR	Central Design Office of Biological Instrument Making	—	—	ANKOM-2m	—
United States	New Brunswick	Multigen Bioflow M19 Labrofern	Microferm Magnaferm	Fermacell IF	Fermatron
	Lab Line Virtis	— Lab Line Virtis	— 43-100	— —	— —
Japan	Marubishi	—	MD-125 MD-500 M7-8 MSI	MTF-573 MSI-U MPF MPF-U	PUC-MSI-U-500
Sweden	LKB	Polyferm 1607	—	Ultroferm 1601	—
	Chemoferm	Chemoferm	—	—	—
	Electrolux Fermentation	—	—	EF	—
FRG	Eschweier	—	—	Kiel	—
	Braun Melsinger	—	—	Biostat	—
Switzerland	Chemap	—	—	Chemap	—
Czechoslovakia	Kovo	—	—	Kovo	—

The Ultroferm model 1601 has a container 2 to 12 l in volume, made of heat-resistant glass. The monitoring system includes units to check the speed of mixing, temperature, pH and Eh of dissolved oxygen, foam quenching, aeration, delivery of nutrient medium, analog and digital display and scanner, that show the parameters in the course of the technological process. The rate of rotation of the mixer can be adjusted in the range of 10-1500 r/min with accuracy of ±1.5%. There is a magnetic drive for the shafts of the mixer and mechanical foam quencher. The foam suppressor shaft rotation rate is 1350 r/min. It is also possible to suppress foam chemically in accordance with a set program. The temperature is regulated in the range of 4-69.9°C with accuracy of ±0.1°C by means of a 400-W heating element installed in the bottom part of the apparatus. The unit for control of pH and Eh automatically maintains the pH with accuracy of 0.1 in the range of 2 to 10, and with accuracy of 20 mV in the range of -990 to 990 mV. The required pH, like the other parameters, is set by a combination of digits. When the pH deviates from the set value a pump is automatically turned on that delivers acid or alkali. The apparatus can be sterilized with steam without being disassembled, since pH and pO_2 are measured with autoclaved electrodes. Maximum output of gas for aeration constitutes 15 l/min. The system of continuous cultivation includes a unit for graduated delivery of nutrient medium, which has a peristaltic pump with two channels, and the maximum productivity of each of them is 2990 ml/h.

The fourth group refers to apparatus, in which computers are used to control the technological process [8], for example, the fermentation apparatus called Permatron-3, which is intended for aerobic cultivation of microorganisms in industry or large scientific research laboratories. It consists of a container 75 to 500 l in size, measuring complex and computer. There are containers with nutrient medium, acid-base and anti-foam additives in the bottom part of the front panel of the measuring unit. Maximum pressure in the apparatus is 3.4 atm. The rate of mixing is regulated in the range of 30-500 r/min. The shaft of the three-turbine mixer has a double seal made of tungsten carbide. The required temperature, in the range of 5 to 60°C, is maintained by means of two refrigerators and steam converter, which also serves as a sterilizer. The sterilization system provides for automatic sterilization of the apparatus, containers with reagents, filters and tubing. The aeration system can deliver up to 360 l/min air into the apparatus or, when necessary, nitrogen or oxygen. Such parameters as pH, Eh and pO_2 are measured, recorded and regulated automatically. Analysis is made of composition of discharged gases with a paramagnetic oxygen analyzer and infrared carbon dioxide analyzer. The device can be equipped with a chemical analyzer to determine the concentration of carbohydrates, total nitrogen content of filtered fluid, chlorine and phosphate content, and optical density of the medium. The values of the measured parameters of the technological process are displayed on a numerical panel by means of an automatic printer. An RDR-11/20 computer, which is connected to the measuring unit, processes inputted information and controls the ongoing cultivation process.

Conclusions

1. The series produced installations for culturing microorganisms can be divided into four groups, which differ in number of instruments and degree of automation of the technological process.

2. The fourth group of apparatus, in which computers are used to control the process, is the most refined technically and technologically.

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RAISING THE EFFECTIVENESS OF PRIORITY RESEARCH IN SCIENTIFIC INSTITUTIONS OF THE USSR ACADEMY OF MEDICAL SCIENCES

Moscow VESTNIK AKADEMII MEDITSINSKIKH NAUK SSSR in Russian No 4, 1980 pp 22-28

[Article by A. M. Chernukh, B. V. Morozov, and G. V. Pogodayev]

[Text] The part played by management of science in raising the effectiveness of scientific research is growing an especially great deal in the modern scientific-technical revolution. Science and scientific activity have only recently started to be viewed as objects of organization and management.

The CPSU Central Committee and USSR Council of Ministers decree "On Improving Planning and Strengthening the Influence of the Economic Mechanism on Increasing Production Efficiency and Work Quality" (1979) notes the need for concentrating efforts on attaining the most important goals, and obtaining the planned end results in maximally short time. This means that management organs must deeply study the organization of scientific research and the use of modern methods to plan and coordinate scientific work. These goals must also be sought because the present stage of science's development is typified not by extensive growth in scientific potential, which would mean that we could achieve the necessary results by amassing larger amounts of scientific research, but rather by intensive utilization of the scientific potential already available, by raising the effectiveness of all units responsible for organization and management of scientific research.

Despite the obvious significant complexity of managing scientific activity, this problem requires the most persistent attention and research today. In this connection it would be important to determine the most important scientific directions in medicine, ones that would permit preferential development of an entire complex of research aimed at acquiring important results required on priority.

Priority research performed at the level of scientific discovery would be the most significant result of scientific activity. Legal protection of scientific discoveries, [illegible] was introduced for the first time in history in our country, is an indication of the importance attached to the ever-increasing role of science in the life of the society. According to the "Statute on Discoveries, Inventions, and Efficiency Proposals" approved by a USSR Council of Ministers decree (1973), establishment of formerly unknown, objectively existing laws, properties, and phenomena of the material world producing fundamental changes in our knowledge is a discovery. It is obvious from this definition that the objects of discoveries may

include laws, properties, and phenomena, the authenticity of which, proven theoretically or experimentally, should not raise doubts. A fundamental change is produced by a discovery in our level of knowledge (this is a measure of how fundamental the research is) if: 1) a new branch of knowledge arises; 2) a complex scientific cognitive problem is solved; 3) inventions are created on the basis of a discovery; 4) authoritative experts recognize it to be a discovery not only in this country but also abroad.

The results of many such projects can bring fame to domestic medical science and raise its authority at the international level. Therefore active implementation of the "Treaty on International Registration of Scientific Discoveries", adopted on the USSR's initiative at a diplomatic conference on scientific discoveries in Geneva in 1978 (the World Organization of Intellectual Ownership), is an important stimulus of scientific research (1).

Quite naturally, in addition to improving the system for managing and coordinating scientific research, we can raise the effectiveness of medical science by performing the research at a modern methodological and technical level and by utilizing the results of other branches of knowledge. Preferential development of fundamental directions (to include in medicine and biology) promoting arisal of new scientific discoveries and creation of highly effective inventions also has an important role (3).

However, fundamental research in biomedical sciences has its own unique features, and it utilizes the achievements of general and molecular biology, chemistry, physics, mathematics, cybernetics, and other subdivisions of science with the purpose of solving problems associated with the prevention, diagnosis, and treatment of various diseases.

Much attention has always been devoted to scientific research on medical theory and practice in our country. Soviet medical scientists are making their contribution to development of domestic science. The achievements of the medical academies of sciences are acquiring increasingly more important significance to solving the social problems associated with Soviet public health. The successes of medical science have made significant improvement of public health, reduction of morbidity, a decrease in overall mortality, and growth in the human life span possible.

The USSR Academy of Medical Sciences unites the largest scientific institutions, ones promoting preferential development of fundamental research and responsible for shaping scientific policy in medicine. This is precisely why the academy should orient the scientific collective toward higher levels of research, such that the novelty and significance of this research would lead to priority developments. Radical solution of many pressing problems in medicine would not be possible today without deep, intensive research in molecular biology and genetics, biochemistry and immunology, general pathology and physiology, pharmacology, and other important fundamental subdivisions of modern medical science.

The development of medical theory is approaching a period in which we can realistically begin searching for ways to synthesize living matter, decoding the processes responsible for organ and tissue differentiation, planning heredity, revealing the nature of malignant growth, clarifying the fine points of the structure and function of viruses, the mechanisms of circulation and transcapillary exchange in their disorders, and the basic laws governing the work of the brain, and so on.

Successful solution of the important problems of modern medicine would obviously be impossible without deep and broad biomedical scientific explorations. One of the main factors responsible for accelerating development and use of progressive scientific achievements in medicine is sensible organization, planning, and prompt revelation of priority studies being conducted in the academy's scientific institutions at the level of discoveries and inventions. Research of this caliber must become the principal content of the work being done by scientific research institutes of the USSR Academy of Medical Sciences. Developing priority research in the academy's scientific centers, we must base ourselves on the idea that this activity should become an inseparable component of scientific research (2).

However, the number of discoveries being made by scientific research institutions of the USSR Academy of Medicial Sciences does not yet fully satisfy the volume and significance of the fundamental research being conducted by these organizations. The level of scientific developments and the materials submitted in claims for discoveries by scientific research institutions of the USSR Academy of Medical Sciences is still low, since not more than a tenth of the material accepted for examination receives a positive response from state scientific-technical expert examination organs. The problem of raising the effectiveness of scientific research in medicine continues to be acute, requiring implementation of a number of organizational, scientific, and practical measures, as well as critical analysis of the status of this work (4). In this connection there would be great practical significance to evaluating research terminating in scientific discoveries, since this would provide a means for determining the effectiveness of the activities of the scientific institutions, and of the results that earn universally high appraisals from state expert examination organs.

In the more than 20 years that the system of state expert examination and registration of discoveries has existed in the USSR State Committee for Inventions and Discoveries, 28 scientific achievements have been recognized to be discoveries in medicine. Of the total number of discoveries in the USSR State Discovery Register (203), 13.8 percent are in the medical area, and half of them are credited to scientists of the USSR Academy of Medical Sciences (Table 1).

Scientific research organizations of the USSR Academy of Medical Sciences are credited with 10 discoveries (35.7 percent), those subordinated to the union republic are credited with 6 (21.4 percent), and those of the USSR Ministry of Public Health are credited with 3 (10.7 percent). Collaboration by research centers of the USSR Academy of Medical Sciences with other scientific institutions led to another three discoveries (10.7 percent), and six (21.4 percent) were produced by nonmedical organizations (USSR Academy of Sciences, USSR Ministry of Higher and Secondary Specialized Education). Thus the activities of scientific organizations of the USSR Academy of Medical Sciences led to 13 discoveries (including ones produced jointly with other institutions).

Comparative analysis of the activities of different groups of scientific research institutions leading to scientific achievements credited as being discoveries would show that organizations of the USSR Academy of Medical Sciences are the most effective (active); while they make up just a tenth of the scientific organizations working on medical problems in the country, they are credited with the largest number of discoveries in medicine (about half).

Table 1. Medical Discoveries in the USSR

No	Year, Diploma and Priority Issued	Diploma No	Area of Medicine	Institution	Subordination,* City	Name of Discovery	Authors
1	1960 1954	7	Biochemistry	Institute of Biological and Medical Chemistry	USSR AMS, Moscow	Enzymatic breakdown of dextran to form glucose	Ye. L. Rosenfel'd, I. S. Lukoeskaya
2	1964 1958	15	Physiology	Institute of Physiology im. I.P. Pavlov	USSR AS, Leningrad	Boundary (contact) membrane digestion	A. M. Ugolev
3	1964 1958	22	Physiology	Moscow State University im. M. V. Lomonosov	USSR Minvuz, Moscow	Reflex-controlled humoral anti-coagulation system regulating the liquid state of blood in the body	B. A. Kudryashov, P. D. Ulitina, G. V. Andreyenko, T. M. Kalishevskaya, G. G. Bazarbazar'yan, V. Ye. Pastorova, N. P. Sytina
4	1965 1956	29	Biochemistry	Institute of Biochemistry im. A. N. Bakh	USSR AS, Moscow	Glucose residue transport by liver enzymes	A. N. Petrova
5	1966 1957	36	Psychiatry	Institute of Psychiatry	RSFSR MPH, Moscow	High silver content in the brain of epileptics	L. M. Londysh
6	1966 1961	39	Biochemistry	Institute of Experimental Medicine	USSR AMS, Leningrad	Regulation of cellular glycolysis rate by a specific protein	S. A. Neyfakh, V. S. Repin
7	1966 1960	48	Radiology	Institute of Biophysics	USSR MPH, Moscow	Fluorine's protective action against radioactive strontium	V. A. Knizhnikov

* AMS--Academy of Medical Sciences; AS--Academy of Sciences; Minvuz--Ministry of Higher and Secondary Specialized Education; MPH--Ministry of Public Health.

[table continued on following page]

No	Year, Diploma and Priority Issued	Diploma No	Area of Medicine	Institution	Subordination, City	Name of Discovery	Authors
8	1967 1957	53	Oncology	Institute of Epidemiology and Microbiology; Institute of Experimental and Clinical Oncology; Institute of Antibiotics	USSR AMS, Moscow	New findings on the pathogenicity of tumor-producing viruses	L. A. Zil'ber, I. N. Kryukova, E. Ya. Svet-Moldavskiy, A. S. Skorikova
9	1968 1951	62	Biochemistry	University im. N. I. Lobachevskiy	USSR Minvuz, Gor'kiy	Assimilation of atmospheric nitrogen by living organisms	M. I. Volskiy
10	1968 1961	63	Physiology	Institute of Biomedical Problems, Institute of Normal and Pathological Physiology, Institute of Developmental Biology im. N. K. Kol'tsov	USSR MPH, USSR AMS, USSR AS, Moscow	Reduction of myocardial norepinephrine concentration in the presence of cardiac hyperfunction and hypertrophy	V. V. Parin, F. Z. Meyerson, M. G. Pshennikova, Yu. N. Manukhin
11	1969 1961	69	Physiology	Institute of Experimental Medicine	USSR AMS, Leningrad	Influence of the posterior hypothalamic nucleus on antibody formation	Ye. A. Korneva, L. M. Khay
12	1969 1967	72	Virology	Institute of Virology im. D. I. Ivanovskiy	USSR AMS, Moscow	Loss of natural resistance to mixoviral infection in animals	G. K. Chepulis, V. M. Zhdanov

[table continued on following page]

No	Year, Diploma and Priority Issued	Diploma No	Area of Medicine	Institution	Subordination, City	Name of Discovery	Authors
13	1969 1966	74	Pharmacology	Institute of Experimental Medicine	USSR AMS, Leningrad	Exhaustion of Norepinephrine in the stomach and other organs, leading to neurogenic dystrophy	S. V. Anichkov, I. S. Zabodskaya, Ye. V. Moreva, V. V. Korkhov, O. N. Zabrodin
14	1970 1969	89	Virology	Institute of Virology im. D. I. Ivanovskiy	USSR AMS, Moscow	Formation of hybrid infectious ribonucleoprotein complexes	F. I. Yershov, V. M. Zhdanov, L. V. Uryvayev
15			Oncology	Institute of Epidemiology and Microbiology, Medical Institute, Institute of Experimental and Clinical Oncology	USSR AMS, RSFSR MPH, Moscow, Astrakhan'	Synthesis of embryo-specific protein by malignant tumors	G. I. Abelev, S. D. Perova, N. I. Kuprina (Khramkova), Yu. S. Tatarinov, N. I. Perevodchikova, N. A. Krayevskiy, I. V. Assekritova
16	1970 1961	92	Physiology	Medical Institute	RSFSR MPH, Krasnodar	Optimum excretion of pepsinogen in the human and animal stomach	N. P. Pyatnitskiy
17	1972 1957	115	Radiology	Institute of Medical Radiology	USSR AMS, Obninsk	Ability of cells to recover from lethal injuries elicited by ionizing radiation	V. I. Korogdin

[table continued on following page]

No	Year, Diploma and Priority Issued	Diploma No	Area of Medicine	Institution	Subordination, City	Name of Discovery	Authors
18	1973 1957	130	Pharmacology	Institute of Experimental Medicine, Medical Institute, Institute of Obstetrics and Gynecology	USSR AMS, RSFSR MPH, Moscow, Volgograd, Leningrad	Control of endocrine gland function by carotid chemoreceptors	S. V. Anichkov, V. Ye. Ryzhenkov, A. A. Belous, A. N. Poskalenko, T. N. Tomilina, Ye. I. Malygina
19	1973 1956	136	Parasitology	Institute of Experimental Medical Parasitology and Helminthology im. L. M. Isayev	Uzbek SSR MPH, Samarkand	Parasitism of mammalian tissues by lamblians	N. A. Dekhkan-Khadzhayeva
20	1974 1965	148	Biophysics	Institute of Higher Nervous Activity and Neurophysiology, Institute of Biological Physics	USSR AS, Moscow, Pushchino	Arisal of paramagnetic nitrosyl iron complexes in the cells of living organisms experiencing hypoxia	Ya. I. Azhipa, L. P. Kayushin, Ye. I. Nikishkin
21	1975 1969	158	Biology	Institute of Oncology	RSFSR MPH, Rostov	Law of development of qualitatively differing, general non-specific adaptive reactions of the body	L. Kh. Garkavi, M. A. Ukolova, Ye. B. Kvakina
22	1976 1972	180	Microbiology	Institute of Tuberculosis	USSR MPH, Moscow	L-transformation of BCG mycobacteria in the body	N. A. Shmelev, I. P. Dorozhkova, Z. S. Zemskova

[table continued on following page]

No	Year, Diploma and Priority Issued	Diploma No	Area of Medicine	Institution	Subordination, City	Name of Discovery	Authors
23	1973 1970	181	Biology	Higher Technical School im. N. E. Bauman	USSR Minvuz, Moscow	Arisal of intrinsic stresses in human and animal bones	V. I. Loshchilov, G. A. Nikolayev, E. P. Babayev
24	1978 1973	187	Biochemistry	All-Union Scientific Center for Cardiology	USSR AMS, Moscow	Regulation of cardiacmuscle contraction intensity by creatine	Ye. I. Chazov, V. N. Smirnov, V. A. Saks, L. V. Rozenshtraukh
25	1978 1967	192	Immunology	Institute of Biophysics	USSR MPH, Moscow	Interaction of lymphocytes with hemopoietic stem cells	R. V. Petrov, L. S. Seslavina
26	1978 1969	193	Immunology	Medical Institute	RSFSR MPH, Voronezh	Inhibition of antibody activity	M. V. Zemskov, N. V. Zhuravleva
27	1979 1969	195	Oncology	Oncological Institute im. P. A. Gertsen	RSFSR MPH, Moscow	Functional antagonism of antibodies in the presence of animal and human leukosis	V. S. Ter-Grigorov, O. Ya. Moskovkina, B. I. Shevelev, V. M. Bergol'ts, I. S. Irlin
28	1979 1969	203	Virology	Institute of Virology im. D. I. Ivanovskiy	USSR AMS, Moscow	Initiation of infection by viral nucleoprotein	A. G. Bukrinskaya, G. K. Vorkunova

Table 2. Distribution of Recorded Discoveries Among Scientific Institutions of the USSR Academy of Medical Sciences

No	Name of Scientific Institution, Location, and Year Founded	Independent	Jointly With Other Organizations	Total
1	Institute of Experimental Medicine (Leningrad, 1890)	3	1	4
2	Institute of Virology im. D. I. Ivanovskiy (Moscow, 1944)	3	--	3
3	Oncological Scientific Center (Moscow, 1951)	--	2	2
4	Institute of Epidemiology and Microbiology im. N. F. Gamaleya (Moscow, 1947)	--	2	2
5	Institute of Obstetrics and Gynecology (Leningrad, 1797)	--	1	1
6	All-Union Scientific Center for Cardiology (Moscow, 1945)	1	--	1
7	Institute of Biological and Medical Chemistry (Moscow, 1944)	1	--	1
8	Institute of New Antibiotics (Moscow, 1953)	--	1	1
9	Institute of General Pathology and Pathological Physiology (Moscow, 1954)	--	1	1
10	Institute of Medical Radiology (Obninsk, 1958)	1	--	1
	Total	9	8	13(17)*

* The difference of 4 is due to simultaneous joint participation by several institutions in particular discoveries.

Data describing actual participation of the collectives of scientific research institutions belonging to the USSR Academy of Medical Sciences in research leading to discoveries are interesting (Table 2). We can see from Table 2 that among the academy's scientific research organizations, the country's oldest scientific medical institution--the USSR Academy of Medical Sciences Institute of Experimental Medicine (Leningrad), the collective of which is credited with four discoveries--has been exhibiting especially fruitful scientific activity; projects completed here at the level of discoveries are revealed promptly. Three scientific discoveries were made in the Institute of Virology imeni D. I. Ivanovskiy, all of them the result of the efforts of just this institute's scientists. Scientists of the Oncological Scientific Center and the Institute of Epidemiology and Microbiology imeni N. F. Gamaleya are credited with two discoveries each.

We can see from Table 2 that more than half of the discoveries (8 out of 13) made by scientific research institutions of the USSR Academy of Medical Sciences were the result of joint work with other organizations of the medical academy. Analyzing the distribution of the number of discoveries recorded per year in a 20-year period (see Table 1), we can conclude that the discoveries have appeared irregularly.

World recognition of many projects conducted by scientists of the USSR Academy of Medical Sciences attests to their scientific and practical significance and importance; these include, for example, discovery of new properties associated with the pathogenicity of tumor-causing viruses, synthesis of embryo-specific protein by malignant tumors, and other discoveries that have become the basis for development of qualitatively new methods for diagnosing and treating a number of serious diseases in the USSR and abroad.

It should be recognized at the same time that despite the successes attained by the academy's scientists, the work of many scientific research institutes of the USSR Academy of Medical Sciences responsible for research on problems of unionwide significance has not been at the required level for many years (and even decades)--that is, they are performing research that is not making fundamental changes in the knowledge of the scientific directions in which they are working. This is doubtlessly slowing down the progress of medical science, to which the USSR Academy of Medical Sciences can make a significant contribution. As of today, only 25 percent of the academy's scientific research institutions (10 out of 40) are conducting research at the level of discoveries; however, the official patent specialists of only half of the scientific organizations of the USSR Academy of Medical Sciences are capable of qualified, systematic work aimed at protecting state interests in priority research. As these data show, not all of the scientific collectives of the USSR Academy of Medical Sciences are satisfying the requirements of the 1973 CPSU Central Committee and USSR Council of Ministers decree "On Further Development of Invention Affairs in the Country, Improvement of the Use of Discoveries, Inventions, and Efficiency Proposals in the National Economy, and Enlargement of Their Role in Acceleration of Scientific-Technical Progress", aimed at raising the effectiveness of research.

Determination of objective indicators with which to evaluate the effectiveness of scientific research in medicine is acquiring great significance today. Occurrence of discoveries within a particular time period (a sufficiently long one, 5-7 years

for example) could serve as one of the main criteria of the contribution made to progress in medical science by institutes responsible for particular problems of unionwide significance fundamental to medicine. Consideration of this indicator would raise both the responsibility and the prestige of the academy institute's scientific collective. Absence of independent patent services in the structural subdivisions--both the central machinery (the Presidium of the USSR Academy of Medical Sciences) and the academy's scientific research institutes--is concurrently hindering effective work aimed at developing priority research in medicine.

Summarizing the activities of scientific institutions of the USSR Academy of Medical Sciences working on discoveries, we can conclude that scientific developments being worked on by scientific research institutes and centers of the USSR Academy of Medical Sciences have an important place in solution of pressing, fundamental medical problems.

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IN THE PRESIDIUM OF THE USSR ACADEMY OF MEDICAL SCIENCES

Moscow VESTNIK AKADEMII MEDITSINSKIKH NAUK SSSR in Russian No 9, 1980 pp 90-92

[Article]

[Text] The presidium of the USSR AMS [Academy of Medical Sciences] heard the report of P. F. Lopatin, chief metrologist of the USSR AMS, concerning the status of metrological support at institutions of the USSR AMS and measures to improve it.

The presidium of the USSR AMS observed that the necessary work was done in the last few years in the system of the USSR AMS to develop the material and technical base of the metrological service. Two base metrological laboratories have been established, which have excellent modern equipment and transportation resources to deliver instruments for a check [inspection]. These laboratories check photoelectric colorimeters, pH meters and a number of medical diagnostic instruments, in addition to general technical measuring equipment. In addition, the laboratories of the Moscow Center for Metrology and Standardization, as well as other agencies, are used extensively to check measuring equipment of scientific research institutes. Senior engineer-metrologists are now on the list of the regular [permanent] staff of institutes of the USSR AMS.

As a result of these steps, the condition of measuring equipment has improved at institutions and organizations of the USSR AMS. At the start of 1977, there was a mean of over 20% of measuring instruments for the entire AMS that had not been checked at the proper time, versus 10% at the start of 1979.

The following institutions and organizations of the USSR AMS have achieved the best results with regard to metrological support of measuring equipment: Institute of General and Communal Hygiene imeni A. N. Sysin, Institute of Virology imeni D. I. Ivanovskiy, Institute of Neurology, Institute of Nutrition, Institute of Poliomyelitis and Viral Encephalitis, Institute of Psychiatry, Institute of Biological and Medical Chemistry and Institute of Epidemiology and Microbiology imeni N. F. Gamaleya.

At the same time, proper attention to questions of metrological support is still not being given by a number of institutions of the USSR AMS. This applies, in particular, to the Institute of Cardiovascular Surgery imeni A. N. Bakulev, Institute of Pediatrics, Institute of Human Morphology, Institute of Industrial Hygiene and Occupational Diseases, Brain Institute and Laboratory of Experimental Biological Models. The most alarming situation with regard to the technical condition of measuring equipment has developed at the Institute of Normal Physiology imeni P. K. Anokhin, where over 85% of the measuring equipment tested in use had not been submitted to checking at the proper time.

The unsatisfactory condition of measuring equipment at these institutions is attributable to poor metrological discipline, unsatisfactory surveillance by institute metrologists over the technical condition and prompt checking of measuring equipment. Questions of metrological support are seldom discussed by scientific councils of the institutes. There is no base in the system of the USSR AMS for checking spectrophotometers, polarimeters, refractometers and a number of other measuring devices that are used in subordinate institutions. Questions dealing with the inspection of these instruments in organizations of the Moscow Center for Metrology and Standardization and other agencies have not been resolved.

To eliminate these flaws and to improve metrological support of institutions and organizations of the USSR AMS, the presidium of the USSR AMS has charged N. V. Razumtsev, head of the Technical Administration, and chief metrologist P. F. Lopatin to take steps to improve the work of metrological laboratories and promptly implement work dealing with checking of measuring instruments; it also indicated that a seminar on the topic of "Tasks for institute metrologists and employees of metrological laboratories of the USSR AMS pertaining to implementation of the complex program of metrological support" should be organized for employees of the metrological service of the USSR AMS, and that there must be intensification of control over the performance of the metrological services, paying special attention to institutions and organizations that presently have a considerable number of unchecked measuring instruments.

It was recommended that the administrators of scientific research institutes and laboratories of the USSR AMS discuss at least once a year, at meetings of scientific councils, questions dealing with the status of metrological support at the institutions and to outline specific measures to resolve them, and that the heads of departments, chief engineers and metrologists be made more responsible for the state of metrological support.

The recommendation was offered to S. S. Gavrilov and V. A. Serebryakov, directors of repair enterprises of the USSR AMS, to take steps for continued development of the material and technical base of metrological laboratories and consolidation of their staffs.

The attention of the directors of the Institute of Normal Physiology, Institute of Pediatrics, Institute of Cardiovascular Surgery imeni A. N. Bakulev, Institute of Human Morphology, Institute of Industrial Hygiene and Occupational Diseases, Brain Institute and head of the Laboratory of Experimental Biological Models was called to the serious flaws in metrological support of their institutions. The deputy administrators for scientific work at these institutions were asked to organize a thorough inspection of the technical condition, records and adherence to rules for operating measuring instruments. On the basis of the results of the inspections, the metrologists of these institutions are to prepare plans of measures, copies of which are to be submitted to P. F. Lopatin, chief metrologist of the USSR AMS.

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The presidium of the USSR AMS heard the report of Prof K. V. Orekhov, director of the Scientific Research Institute of Medical Problems of the North, Siberian Department of the USSR AMS, dealing with a draft program for scientific research on the topic of "Human ecology in the Extreme North."

The presidium of the USSR AMS observed that the submitted draft program includes the study of the most important patterns of human ecology under experimental conditions of the North, and that it conforms with the tasks put to medical science by the 25th CPSU Congress, and the decree adopted by the CC CPSU and USSR Council of Ministers in 1977 "Concerning Measures for Continued Improvement of Public Health."

The draft program deals with the basic directions of theoretical, experimental and clinical medicine that would be instrumental in further improvement of the health status of the public, long and active life and higher reproduction of healthy offspring in the Extreme North.

The presidium of the USSR AMS gave its approval to the main points of the draft program on "Human ecology in the Extreme North" of the Siberian Department of the USSR AMS concerning medicohygienic and biological problems of the North.

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The presidium of the USSR AMS heard the report of Prof V. A. Matyukhin, director of the Scientific Research Institute of Physiology, Siberian Department of the USSR AMS "On a draft regional program for the Siberian Department of the USSR AMS," "Biomedical problems of work-shift organization of labor in regions undergoing industrial development."

The presidium of the USSR AMS observed that the regions of new industrial development in Siberia consist chiefly of territories with few inhabitants and with a rigorous climate. The development under these conditions of new oil, gas and coal mines, and of timber, has caused an intensive influx of migrants, who constitute 97% of the population in some regions. The new climate is straining all functional systems of the migrants during the adaptation period. In addition, the working conditions make it imperative to organize labor in work shifts, which means that brigades of workers experience considerable stress factors when they move rapidly and for a long time away from their customary habitat to the difficult industrial and microclimate conditions. All this makes it imperative to immediately solve a number of basic biomedical problems, after which recommendations can be formed: criteria for screening individuals to work under work-shift conditions, optimum work schedules, setting sanitary and hygienic labor standards, monitoring and improving the health of workers, etc.

The objective of the draft program entitled "Work shifts," under discussion is complex and coordinated work on the above-mentioned problems, together with institutions of other agencies.

The presidium of the USSR AMS expressed its approval of the direction of scientific and practical-scientific work on the regional program as being timely for the development of new industrial regions, and it adopted the regional program. The Scientific Research Institute of Physiology, Siberian Department of the USSR AMS was appointed the chief institution for implementation of the regional program.

* * *

The presidium of the USSR AMS heard the report on the findings of a complex inspection of the work at the Institute of Normal Physiology imeni P. K. Anokhin, USSR AMS.

The presidium of the USSR AMS observed that the work done at the Institute of Normal Physiology imeni P. K. Anokhin, USSR AMS, is based on continued creative development of the teaching of Academician P. K. Anokhin on functional systems of the body.

Work in the main directions of the institute is being pursued in total conformity with the adopted program, and it is based on the leading theoretical theses of P. K. Anokhin concerning functional systems of the body. Some new facts were obtained as a result of the research conducted within the framework of these directions, and conceptions have been expounded that represent the creative elaboration of the scientific ideas of P. K. Anokhin.

New conceptions have been expounded on systems quantation of the purposeful behavioral act, as well as the conception of systemogenesis of the behavioral act. These theoretical theses constituted the methodological foundation for investigation of a number of applied aspects of physiology (physiology of labor and sports). An original conception was formulated on population systemogenesis.

The specific role of central mechanisms, which could lead to cardiovascular disorders in the presence of conflict, was demonstrated in a study of emotional stress. The significance of genetic and acquired factors has been defined in mechanisms of predisposition and resistance to emotional stress. On the basis of this research, methods have been developed for predicting development of cardiovascular disturbances. The hypothesis has been expounded that certain oligopeptides are involved in the formation of various emotional motivational states.

The results of research done at this institute have made it possible to recommend for practical use some of the scientific achievements in the area of industrial physiology, sports and preventive medicine. Recommendations were developed and are already being implemented in the area of prevention of emotional tension in workers and students; original designs of portable stimulators to attenuate pain syndromes are in use at the clinic.

The results of theoretical research conducted at the institute on the mechanisms of maintaining a vertical body position and others have been adopted in the training of the Olympic shooting team.

Over the period covered by the report, the staff of the institute published 606 scientific works, including 1 monograph, 2 books, 7 collections on specific topics, and there are 4 monographs in press. Three author certificates have been issued for inventions, and applications for four others are being considered.

The institute implements extensive compensation for research involving 18 institutions of the USSR Academy of Sciences, USSR AMS and USSR Ministry of Health, and it is actively developing collaboration with institutions and scientists of socialist and capitalistic nations.

The institute serves in an administrative capacity as the chief institution in the nation overseeing the problem of "Mechanisms of systemic organization of functions" within the framework of two all-Union scientific programs: "Functional systems and principles of dynamic organization thereof" and "Emotional stress and its role in the genesis of cerebrovisceral disturbances."

There are 17 scientific research laboratories and 3 independent scientific groups, with a scientific-administrative department, at work at this institute.

However, the presidium of the USSR AMS noted that there were a number of flaws in the work of the institute.

As yet, not all of the institute staff members have learned the methodology of the systems approach with regard to development of theory of functional systems expounded by P. K. Anokhin. There are laboratories within the institute structure that duplicate one another (laboratories of functional neurochemistry, theoretical physiology, molecular neurophysiology and biochemistry). Some laboratories are understaffed and are not adequately furnished with material and technical equipment (the memorial laboratory of neurohistology imeni B. I. Lavrent'yev). The names of some laboratories do not reflect the specific nature of research conducted there.

The laboratory of neuroendocrine regulation must be reorganized; the projects of this laboratory do not cover the broad front of research in the field of systems physiology, which are needed because of the direction of the problems that are being worked on; modern methods for studying hormones are not used in this laboratory.

Biochemical and morphological research is not being conducted on a sufficient scale at the institute, and there are major difficulties related to the extreme shortage of work space, physical separation thereof and unsafe condition of facilities that are in use.

The institute is poorly equipped with computer technology for ongoing processing of experimental data, and it does not have a highly skilled engineering service. The organization of the metrological service is unsatisfactory; there is irregular and inadequate supply of equipment and chemical reagents, as well as laboratory animals.

Having approved of the performance of the Institute of Normal Physiology imeni P. K. Anokhin, USSR AMS, and the main directions of its scientific research, the presidium of the USSR AMS has made it incumbent upon K. V. Sudakov, corresponding member of the USSR AMS, who is the director of this institute, to implement the following: continue with the work of the institute staff to extend the methodological bases for creative development of the teaching on functional systems of the organism expounded by Academician P. K. Anokhin; to develop,within 1 month, a plan of administrative measures to eliminate the above-mentioned flaws; to consider the question of upgrading the structure of the institute in the light of the comments that were made, paying special attention to strengthening the laboratories created at the instigation of P. K. Anokhin; to improve the laboratory of neuroendocrine regulation, and to expand biochemical and morphological research.

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COMPREHENSIVE PROGRAMS AT MEDICAL CENTERS IN SIBERIA

Moscow ZDOROV'YE in Russian No 9, 1980 pp 2-4

[Article by N. R. Deryapa, chief scientific secretary of the Siberian Department of the USSR Academy of Medical Sciences and corresponding member of the USSR Academy of Medical Sciences]

[Text] We have been working during the last five years to implement the decisions of the 25th CPSU Congress providing for the further development of research on the leading medical-biological, social-hygiene and medical problems.

Along with the study of the most important clinical aspects of medicine we have given much attention to studying the various aspects of vital activity in the healthy human, primarily the patterns of adaptation in man to the new so-called subextreme climatic, geographic and social-production conditions. This question is of paramount importance for the inhabitants of Siberia, the Far East and the Far North.

At one time, adaptation by the first generations of Siberians to the new conditions took decades and even centuries. Now it is vitally necessary to learn how to control this process. Because of the preferential economic development of regions in Siberia, the Far East and the Far North and the creation of territorial-production complexes, migration from the west and south regions of the country has increased sharply. The need has arisen to learn in the shortest possible time, on the one hand, the ways in which the various climatic and geographical factors affect the human body; and on the other, the molecular, cellular, organic and systemic mechanisms of adaptation to them. Simply put, it has been necessary to find the weak links in the unified system that protects the body from the adverse effects of the environment, and to develop effective physiological methods to enhance health and prevent disease. All the avenues in this kind of research were conceived and combined in the "Human Adaptation" program, the implementation of which literally every medical-biological institute in the country is adding its contribution. Today, on the eve of the 26th CPSU Congress we are able to state with satisfaction that during the years of the 10th Five-Year Plan much data has been obtained that is of value for an understanding of adaptive mechanisms and for dealing effectively with the adverse effect of unusual environmental conditions on the human body.

One important result from the work of the scientists of the Siberian Department of the USSR Academy of Medical Sciences has been the discovery of the syndrome of polar stress that develops in the body in response to the prolonged effect of subextreme factors. At its basis lies the change in the metabolic complex, primarily energy exchange in the cellular membranes. The fact is that under normal conditions the body derives energy during the process of the oxidation equally from carbohydrates or fats, while in the polar stress syndrome, the oxidation of fats becomes preferential. This condition, which determines a certain level of functioning for all body systems, is not really a pathology or disease. In certain situations, however--when the qualitative changes built up in the cellular structures reach a critical magnitude--they can "clear the way" for atherosclerosis, ischemic heart disease, arterial hypertension, hemolytic anemia and other diseases.

The scientists of the Siberian Department of the USSR Academy of Medical Sciences have undertaken a series of static and expeditionary research projects in order to arm the practicing physician with methods of preventing these shifts. One of the methods developed during the process of this research is the switching of new settlers to a rational, balanced diet worked out by generations of Siberians, in particular the use of venison and deer fat, marine animals, and fish from sources in the north. Some of the correcting diets suggested by our scientists have already been put into use.

Data important for gerontology and pediatrics have been obtained as the result of joint research conducted in the regions of north Siberia by specialists from the Novosibirsk Institute of Clinical and Experimental Medicine and the Tomsk Medical Institute. Retardation and suppression of immune responses have been found in new settlers. These changes are of a phased nature and could be one of the reasons for the protracted course of infectious and noninfectious diseases and of inflammatory processes and the slower healing of injuries. It has also been found that the phased nature of the immune response discovered must be taken into account when drawing up the calendar for prophylactic vaccinations in Siberia, the Far East and the Far North.

Using the "Human Adaptation" program as a base, the Presidium of the Siberian Department of the USSR Academy of Medical Sciences has drawn up a series of goal-oriented regional subprograms.

The general aim of the "The North--Human Ecology" subprogram is to maintain and to enhance the health of indigenous and immigrant populations of the Far North. The head institute is the Institute of Medical Problems of the North located in Krasnoyarsk, and others participating in the implementation of the program include 34 scientific research and medical institutes belonging to our academy, the union and republic ministries of health, and the Siberian Department and the Far Eastern Scientific Center both of the USSR Academy of Sciences.

The "Work Shift" subprogram is also extraordinarily important. Started on the initiative of scientists at the Novosibirsk Institute of Physiology in cooperation with specialists from the Tyumen' Medical Institute, it now includes personnel from another 17 of the country's establishments in Saratov, Ufa and

other cities. A comprehensive study of production and everyday conditions and the state of health of contingents of shift workers by physicians of various specialities has made it possible within a short time to draw up temporary guidelines for rules for occupational selection, for working and rest conditions, and for diets for those engaged in surveying and in oil and gas recovery work north of Tyumenkaya Oblast. Work on this subprogram continues.

The "Environmental Hygiene and Maintenance of Human Health (city, region)" subprogram is of great significance for the industrial centers. It provides for the drawing up of measures to insure the successful fulfillment of plan targets by industrial enterprises while simultaneously maintaining the health of the population and an environment beneficial to life.

The function of information has been entrusted to treatment and prophylactic establishments. Alarm signals (increased occurrence of diseases or industrial discharges contaminating the atmosphere at a populated point) are received by the "City Health Automated Control System", are processed and then passed on to the authority on whom correction of the situation depends. The head institute of this subprogram is the Scientific Research Institute of Comprehensive Problems of Hygiene and Occupational Diseases in Novokuznetsk. The introduction of the "City Health Automated Control System" in the Kuzbas territorial-industrial complex has already had a tangible effect. Similar systems are being introduced in other cities in the east of the country, in particular in Noril'sk and Vladivostok. Experience gained in setting up a data base for health has also been passed on to our Bulgarian friends.

During the 10th Five-Year Plan a qualitatively new stage began in the development of the medical sciences in the east. Strengthening of the material and technical base and the increase in the numbers of scientific personnel are enabling us to improve planning and coordination of scientific research, assimulate scientific developments more rapidly in extensive clinical practice, and provide qualified personnel for medical teams in the eastern regions.

In preparing to meet the 26th CPSU Congress in a worthy manner, we should display even greater expectations of ourselves; we should reveal defects, poor work and oversights, and again and again consider and discuss our plans for the 11th Five-Year Plan. This was spoken of, particularly in the clinics and laboratories of the Siberian Department of the USSR Academy of Medical Sciences and at meetings and assemblies devoted to the CPSU Central Committee June (1980) Plenum, and was pointed out at the aktiv of the CPSU Novosibirsk oblast and city committees.

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ALL-UNION INTEGRATED PROGRAM OF SCIENTIFIC RESEARCH IN BIOPHARMACEUTICS

Moscow FARMATSIYA in Russian No 5, 1980 pp 1-4

[A. I. Tentsova, G. S. Kiseleva, S. A. Valevko, and S. F. Vasil'yeva, All-Union Scientific Research Institute of Pharmaceutics, Moscow]

[Text] The planning of specific programs to deal with the most important problems in pharmaceutics is within the overall complex of issues being worked on within the framework of the unionwide "Pharmaceutics" problem of the USSR Academy of Medical Sciences.

Research in biopharmaceutics acquired great significance in the last decade; this research has established the biological significance of the processes associated with acquisition of medicines, the physicochemical state of the substances involved, the quality and quantity of formers, the form of medicine, medicine production procedures, and so on.

However, despite significant successes, a deep theoretical foundation has not as yet been established for scientific research in this area and, what is especially important, the scientific research has not yet enjoyed practical implementation.

The need has now risen for creating the conditions for studying the fundamental problems of biopharmaceutics. Such research would require unification of the efforts of scientists in different specialties. The need for close ties among different specialists is also emphasized by the requirements presently imposed on research on medicinal forms by the USSR Ministry of Public Health and WHO.

Research in biopharmaceutics is being conducted in our country on a sufficiently broad front by pharmaceutical institutions, school departments, and scientific research institutions, but it is impossible to solve the problems of biopharmaceutics today without the participation of physical chemists, biochemists, pharmacologists, physiologists, and others.

Considerable experimental and theoretical material accumulated by pharmaceutical institutes and school departments in biopharmaceutics has made it possible to compile the All-Union Integrated Program of Scientific Research in Biopharmaceutics.

This program is based on proposals received by the problematic commission from researchers working on the problems as well as from institutes of the USSR Academy of Sciences, the USSR Academy of Medical Sciences, the Ministry of Medical Industry, and other institutions.

The program also reflects new research directions that appear promising to the problematic commission.

The main goal of the program is to develop effective, sensible medicinal forms, to create and use auxiliary compounds that promote optimum expression of the pharmacological properties of a preparation, to improve medicine production processes, to raise the effectiveness of the methods of medicine analysis, and to acquire new data on biological availability.

The program includes four basic directions, each of which contains its own sections and subsections, together with concrete research tasks.

The first direction, "The Theoretical Fundamentals of Biopharmaceutics and Experimental Study of Pharmaceutical Factors", foresees research on the influence of the physicochemical properties of medicines upon their biological activity. This research is permitting us to acquire new data on the influence of particle size, polymorphism, solubility, and other physicochemical characteristics of medicines upon their assimilation and the nature of their metabolism and elimination. The research is also permitting us to establish the mechanism of interaction between the structure of crystals and solvates on one hand and their physical and chemical properties and biological availability on the other (All-Union Scientific Research Institute of Pharmaceutics--VNIIF, Pyatigorsk Pharmaceutical Institute, and Moscow Medical Institute No 1--MMI No 1).

Biopharmaceutical investigation of auxiliary substances used in the production of soft, solid, and liquid medicines has the objective of revealing the laws governing interaction between medicinal preparations and auxiliary components. Such research is to be used as a basis for creating and using highly effective vehicles, to include ones with prescribed physicochemical properties insuring optimum therapeutic activity, and for finding new auxiliary substances to be used in the creation of promising medicines (VNIIF, the Pyatigorsk and Perm' pharmaceutical institutes, the Kursk Medical Institute, MMI No 1, the Riga and Ryazan' medical institutes, the Georgian SSR Academy of Sciences Pharmacochemical Institute, and the Leningrad Institute of Chemico-Pharmaceuticals--LKhFI).

The production processes used in acquisition of medicines is one of the important pharmaceutical factors. By revealing the role played by production processes and their relationship to biological availability, and by improving the methods of medicine manufacture, we will be able to develop effective medicinal forms and preclude their therapeutic nonequivalence (VNIIF, Pyatigorsk Pharmaceutical Institute, MMI No 1, the L'vov and Ryazan' medical institutes, and the "Olaynfarm" Production Association of the USSR Ministry of Medical Industry).

Important tasks of biopharmaceutics, from the point of view of its status as a technological subdivision, include creation of sensible and new medicinal forms, and acquisition of new experimental and clinical data on the influence of the form of medicine upon the pharmacotherapeutic action of medicines. There are four concrete tasks in this case: development of sensible medicinal forms insuring optimum activity of the medicine; investigation of long-acting medicinal forms, and their experimental *in vitro* and *in vivo* analysis; investigation of the possibilities for creating new selective-action medicinal forms; creation of medicines tailored to particular age groups, and their biopharmaceutical evaluation.

work on these tasks will make it possible to propose the most sensible medicinal forms for anticonvulsive, psychotropic, hormonal, antihistamine, sulfanilamide, and other groups of preparations, to develop the theoretical aspect and methods of prolonged action of medicinal substances, and to create long-acting forms of medicine (eyedrops, microcapsules, granules, (spansuly), and so on); to develop, on the basis of theoretical and experimental material, the procedures for forming liposomes from native and synthetic lipids, and to study the conditions for binding a number of medicinal substances with liposomes to permit evaluation of the influence of membranes upon entry of medicines into the cell; to develop the scientific principles of creating medicines tailored to particular age groups, acquire new data on the mechanism of interaction between unique features associated with the age of the individual and preparation assimilation, distribution, and elimination, and to develop requirements of children's medicines (VNIIF, the Pyatigorsk, Perm', and Khar'kov pharmaceutical institutes, the LKhPI, MMI No 1, the Kaunas, Kishinev, Kursk, L'vov, Riga, and Ryazan' medical institutes, the Georgian SSR Academy of Sciences Pharmacochemical Institute, and the Latvian SSR Academy of Sciences Institute of Organic Synthesis.

Today, at a time when extensive work is being done throughout the world to find new physiologically active substances, revelation of new classes of physiologically active substances and creation of medicines on their basis are important. The program includes developing approaches to comparative evaluation of physiologically active substances and medicinal forms made on their basis, and developing a system for initial selection of potential physiologically active substances having receptor action. This will make it possible to introduce methods and quantitative indices for quick assessment of the pharmacological properties of known and new medicinal preparations, and to reveal potential medicinal substances among compounds having unique chemical structure (Scientific Research Institute of Biological Testing of Chemical Compounds--NIIBIKhS).

The problem of the stability of medicinal preparations and medicinal forms has always been important to pharmaceutics. The program foresees investigation of the mechanisms of radical-oxidative processes occurring in the aging of medicines, research on the influence preparation stability has on the biological availability of medicines, and development of the scientific principles of selecting stabilizers (VNIIF, Pyatigorsk Pharmaceutical Institute, MMI No 1, the L'vov and Ryazan' medical institutes, NIIBIKhS).

The program's second direction includes experimental investigation of the influence of biological, physiological, biochemical, and ecological factors upon the pharmacokinetics of medicinal preparations. The objective of this section of the program is to reveal the laws governing the influence of external and internal environmental factors, biological rhythms, simultaneously prescribed medicines, and so on upon assimilation, distribution, and elimination of medicines from the body. The results can be used to determine the conditions for prescribing such medicines. Research will be conducted on the mechanisms of action of medical preparations at the molecular and subcellular levels, new data will be acquired on the mechanism of action of preparations in the phenothiazine series, and sensible ways of their administration will be established (VNIIF).

Research on the influence factors of the external and internal environment have on medicine assimilation and elimination will help us reveal the unique pharmacokinetics of some preparations in the body as it responds to particular living conditions, temperatures, and physical loads (LKhFI, and the Ryazan' and Tyumen' medical institutes); research on the influence of biological rhythms upon preparation activity will make it possible to establish the influence of diurnal rhythms upon the basic characteristics of lipid metabolism and preparation pharmacokinetics (LKhFI, Tyumen' Medical Institute). Research will be conducted on the biopharmaceutical aspects of such use of a number of preparations, as well as on the role of food composition and the pH of the contents of the gastrointestinal tract upon medicine absorption and elimination (MMI No 1, and the Ryazan' and Kursk medical institutes).

The pharmacogenetic aspects of obtaining and studying medicinal agents has been of interest in recent years. Emphasis is placed on development of the theoretical principles of designing medicinal forms intended for use by patients of particular phenotypes (NIIBIKhS).

The third direction--biological availability of medicines and the methods of its determination--is presently one of the most important. Solution of this problem will make it possible to develop the theoretical aspects and practical recommendations of determining biological availability of medicines as a criterion for evaluating the quality and effectiveness of medicinal preparations. The methods and instruments used to determine biological availability *in vitro* and *in vivo* will be developed and subjected to comparative evaluation. This will make it possible to suggest practical recommendations on their use in determining the biological availability of medicines (VNIIF).

Plans are being made to make a theoretical and practical analysis of the possibility for modeling assimilation and elimination of preparations administered by pathways other than intravenous. Application of precise correlation methods will make it possible to reduce the number of experiments required to determine biological availability in animals, and to write scientifically grounded recommendations on choice of optimum medicinal forms (VNIIF, MMI No 1). Tests to evaluate the quality of medicinal forms will be developed, recommendations on forecasting the cases of their possible therapeutic inadequacy will be prepared, and the most sensible schemes for studying medicinal forms will be developed (VNIIF).

The fourth direction involves improvement and development of present methods for determining preparations and their metabolites in biological fluids and body tissues.

The objective of this direction is to improve existing methods and achieve application of new, highly sensitive methods of pharmaceutical analysis of medicinal agents in biological fluids and tissues. Research will be conducted on oxidation, reduction, hydrolysis, acetylation, and alkylation of a number of medicinal substances (VNIIF, the Pyatigorsk and Khar'kov pharmaceutical institutes, LKhFI, MMI No 1, the Kishinev, Kursk, Riga, Ryazan' and Tyumen' medical institutes, and the Georgian SSR Academy of Sciences Pharmacochemical Institute).

Pharmaceutical, medical, and scientific research institutes collaborating with the all-Union pharmaceutics problematic commission of the USSR Academy of Medical Sciences, and a number of institutes of the USSR Ministry of Medical Industry, USSR Academy of Medical Sciences, USSR Academy of Sciences, and others are participating in the program's implementation today.

However, the problematic commission will gratefully and attentively examine all proposals for new directions of scientific research in biopharmaceutics, and for expanding the number of participants of the program.

The problematic commission plans to hold working conferences on different sections of the program with the goal of developing unified approaches to solving the most important problems and assessing the research procedures and results.

All scientific research associated with the program is being conducted as part of the scientific research plan of each institute or school department. Plans for particular years and reports of work completion are to be submitted by deadlines established in an order of the USSR Minister of Public Health entitled "The All-Union Integrated Biopharmaceutic Program".

At the request of the problematic commission, a detailed report on the results of scientific research in the integrated program, on its practical introduction, or on its phases must be submitted to the main institute once every 2 years.

Scientific research results that are accepted and approved by the main institute will be treated as introduced.

Implementation of the program will make it possible to solve a large number of interesting problems in biopharmaceutics, and to achieve practical introduction of proposals of interest to medicine and pharmaceutics.

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EFFECT OF PULSED NOISE ON MAN

Moscow VOYENNO-MEDITSINSKIY ZHURNAL in Russian No 12, 1980 pp 44-46

[Article by P. I. Mel'nichenko, capt med serv]

[Text] Our objective was to study the systemic reaction of healthy young people to intensive pulsed noise, taking into consideration the nature, severity of disturbances and time of restoration of their initial functional state. The frequency range of pulsed noise was 0-10 kHz, with prevalence of energy maximum in the range of 0-400 Hz. The subjects were exposed once to 5 to 50 pulses, each of which lasted up to 10 ms, with 10 s intervals between them. A special measuring and recording channel was used to record the physical characteristics of the noise, which enabled us to record noises in the frequency range of 1 Hz to 20 kHz and dynamic range of 0-100 kPa. We used a piezoelectric pressure transducer as the signal receiver. Spectral analysis was made on a specially developed program, using a computer.

We assessed the effect of pulsed noise on the body on the basis of tonal audiometry (air and bone conduction), heart and respiration rates, and arterial pressure. We conducted an electrocardiographic examination, used a modified cancellation test and tested the reaction to a moving object (RMO). The questionnaire method was used to assess the subjects' subjective condition.

In our study of the reactions to diverse noises, included pulsed noise, we used parameter VSP_2, which characterizes a man's hearing threshold 2 min after exposure to the tested factor. In view of the fact that the tests were conducted under physiological ["natural"] conditions, we extended to 15 min ($VSP_{1,5}$) the time of examination of changes in hearing thresholds (in the laboratory) after exposure to noises. In order to determine the time of restoration of these thresholds to the base levels we determined them many times every 15 min.

Hearing was tested in a special soundproof chamber, the parameters of which conformed with the specifications of GOST 12.4.05-78. An ATK-4 audiometer of the Medikor Firm was used to determine hearing thresholds. The results of testing thresholds for air conduction are listed in Table 1. The averaged levels of hearing loss were calculated on the basis of data obtained for subjects with poorer hearing.

The figures listed in Table 1 indicate that there is a correlation between VSP_2 and intensity of noise, as well as number of pulses. At the same noise level,

when the number of pulses was doubled it also took about twice as long for the hearing thresholds to be restored.

Table 1. Hearing loss and time of restoration in the subjects

Noise level, dB	Number of pulses	VSP_{15} tested frequencies, Hz				Recovery time, min
		500	1000	2000	4000	
163	25	0	0	5±0.41	4.4±0.6	30
	50	0	2.5±0.2	1.1±0.3	5±0.62	50-60
165	25	1±0.17	3.1±0.31	2±0.19	6±0.91	60-80
	50	3.5±0.18	3.5±0.42	3.7±0.3	10±0.76	120-140
166	25	5±0.5	4.2±0.61	5.7±0.78	13±0.58	120-140
	50	5±1	5±0.44	11±0.49	20±1.2	240-260
167.5	13	5±0.6	5±0.27	15±1.68	35±1.7	240-300
174	5	10±0.5	15±1	17±1.5	35±1.6	Over 8 h

Table 2. Results of cancellation tests done by subjects

Noise level, dB	Parameters studied		
	before exposure	during exposure	after exposure
	Efficiency and fatigability, number of rings processed per 30 s		
163	14.76±1.62	8.57±0.84	13.59±1.7
165	18.93±2.89	-	16.5±1.91
166	15.84±2.42	-	14.92±2.49
	Degree of adjustment to task, arbitrary units		
163	0.85±0.04	1.3±0.21	0.91±0.07
165	0.74±0.03	-	0.86±0.01
166	0.99±0.16	-	0.79±0.19
	Carrying capacity, bits/s		
163	1.46±0.16	0.85±0.08	1.36±0.13
165	1.89±0.29	-	1.65±0.11
166	1.57±0.25	-	1.47±0.25

Studies of the state of the central nervous system by the method of cancellation tests (A. M. Parachev, V. A. Mozin, 1970) made it possible to demonstrate a direct link between the intensity of a noise and quality of performance, as compared to base data. Thus, with exposure to noise of 163, 165 and 166 dB, the number of individuals with changes in test results constituted 17.3, 28.4 and 43%, respectively. There was also a distinct correlation between quality of performance of the cancellation test and intensity and duration of exposure (Table 2).

As can be seen in Table 2, there was some decline of efficiency and increase of fatigability, poorer adjustment and diminished throughput under the influence of

noise. However, statistical processing revealed that there are no reliable differences between the base data and those obtained after the tests. At the same time, we demonstrated an appreciable difference between the results obtained during exposure to noise, base results and those following exposure to noise ($P<0.05$). This justifies consideration of the changes in functional state of the central nervous system as initial and transient. The demonstrated deviations also indicate that one should expect more profound disturbances with increase in intensity of noise.

The prevalence of inhibitory processes demonstrated in the cancellation tests was also corroborated in our study of the reactions to a moving object. For example, with noise of 163 dB there was no change in number of correct answers, while the number of delayed responses increased by 1.6%. Even greater changes were demonstrated with exposure to noise of 165 dB: the number of correct responses dropped by 10%, while the number of delayed ones increased by 8.7%. From 3 to 4 h were required to restore the base RMO parameters.

Our findings are consistent with the data of other authors (S. I. Gorshkov et al., 1965; G. A. Suvorov, A. M. Likhnitskiy, 1975, and others), who also reported the inhibitory influence of pulsed noise.

Many researchers found that the cardiovascular system was quite vulnerable to the factor under study (S. V. Alekseyev, G. A. Suvorov, 1965; A. V. Kadyskin, 1968, and others). We examined its state by means of electrocardiography, on the basis of which we determined the cardiac index, systolic index and the autonomic index of Kerdo. We failed to demonstrate appreciable deviations on the ECG, as well as the above indexes. Noticeable changes were found in dynamics of heart rate and arterial pressure (Table 3).

Table 3. Dynamics of subjects' heart rate and arterial pressure

Noise level, dB	Subjects presenting changes, %	Breakdown of changes			
		tachycardia	bradycardia	hypertension	hypotension
163	33.4	66.6	33.4	50	50
165	37.5	66.8	33.2	66.7	33.3
166	41.6	60	40	61.8	38.2
167.5	75	55.1	44.9	50	50

With increase in intensity of pulsed noise there was an increase in number of subjects with functional changes in the cardiovascular system. The changes in heart rate and arterial pressure differed in direction. Thus, with increase in noise intensity there was an increase in number of subjects with tachycardia. However, when high levels were reached (over 165 dB), many subjects presented slowing of the pulse. An analogous reaction of the cardiovascular system was also reported by other authors. A. V. Kadyskin (1968), who studied the effects of stable noise, demonstrated that brief acceleration of the pulse was followed by progressive slowing.

We failed to demonstrate a clearcut correlation between intensity of noise and reaction of arterial pressure. G. A. Suvorov, A. M. Likhnitskiy (1975) and other

researchers arrived at the same conclusion. Perhaps, this is attributable to the fact that pulsed noise affects primarily the auditory analyzer and central nervous system, which are responsible for the formation of the body's general reaction. Here, the individual distinctions of a man, his sensitivity to the effect of this factor are significant.

The studied parameters of cardiovascular system function reverted to the base levels within 1-2 h. There were no appreciable changes in the subjects' respiratory rate.

The answers on the questionnaire revealed that there was a marked relationship between the subjects' subjective state and intensity of the noise. A significant worsening of subjective state was noted with very loud noise (165 dB and higher).

Thus, pulsed noise has an adverse effect on different functional systems of man, which confirms the opinion of Soviet scientists (Ye. Ts. Andreyeva-Galanina et al., 1972; G. A. Suvorov, A. M. Likhnitskiy, 1975, and others) that a complex approach is needed to the study of this factor. The nature and severity of the changes, as well as normalization thereof, depend on the intensity of the noise, duration of exposure and number of pulses per unit time. Particularly substantial disturbances occur in the functional state of the organism with exposure to pulsed noise of over 165 dB intensity. In our opinion, this level can be viewed as a guideline when substantiating the permissible levels of pulsed noises with similar physical parameters.

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MEDICAL-DEMOGRAPHIC AND SOCIO-HYGIENE REASONS AND FACTORS FOR ABORTION

Moscow ZDRAVOOKHRANENIYE ROSSIYSKOY FEDERATSII in Russian No 9, 1980 pp 27-31

[Article by A. A. Popov, Moscow]

[Text] Induced abortion attracts the attention of socio-hygienists not so much in itself as a purely medical phenomenon as because of its influence on the birthrate.

Abortion is emerging as a factor of change in the birthrate because of its influence both on the woman's health and on her subseqent fertility. Abortion is a method of regulating the birthrate by virtue of its exceptional incidence compared with contraceptive methods and devices.

The problem of the incidence of induced abortion is that with the arisal of a socially dictated need to regulate the birthrate and having been given a real opportunity to do so, a significant portion of the population either prefers abortion or is compelled to have it because of the low demographic effectiveness of contraceptive method and devices. The reason for this preference on one hand and for the low demographic effectiveness of contraceptive methods and devices on the other, is the essence of the problem of induced abortion.

The extent of its incidence depends on the degree to which the socio-economic and sociopsychological factors responsible for the undesirability of pregnancy and the birth of a child are manifested, the prevalence of contraceptive methods and devices and the population's information in this field and also on the low demographic effectiveness of the indicated methods and devices.

This approach to investigation of the problem of induced abortion from the medico-demographic perspective exists in the socio-hygiene literature of recent years, but unfortunately it has received comprehensive treatment only in the works of certain authors. Along with it the traditional, descriptive approach which, moreover, is often associated with scientific bias, also remains as equipment. This is true despite the obvious scientific and practical inequality of the indicated approaches.

The reasons for and factors of induced abortion must be isolated and delimited. The extent to which the reason for limitation of the birthrate influences the women of a group under study--in other words, the manifestation of modern reproductive behavior--can be evaluated by taking into consideration these women's level of social development, i.e., on the basis of the group's social characteristics (social class composition, national and ethnic affiliation, education, place of residence--in the city or the country, professional skills, etc.).

The socio-hygiene literature presents the completest description of the factors of and motives for induced abortion, which figure as its causes in a number of cases.

The births-abortions ratio is the most often encountered of the indices of the incidence of induced abortion. In the USSR the incidence of induced abortion fluctates from 1:2.7 (Altayskiy Kray)[1] to 1:5.9 (Alma-Ata).[2] The reason for such differences is the nonidentical degree of manifestation of modern reproductive behavior, which depends on the social status of the group under investigation and the different regional manifestation of the factors which determine the extent of the incidence of abortion.

In some cases, in dependence on the regional manifestation of the factors of abortion the fluctuations in its level reach considerable dimensions even within neighboring districts. Thus, within the boundaries of the Georgian SSR the birth-abortions ratio fluctuates from 1:1.2 to 4:1.[3]

Accordingly the abortion dynamics indices must be understood as having specific significance for the social group under investigation and for the region being studied. Thus, in Tashkent abortions increased on the average by 44.9 percent from 1955 to 1973;[4] in Udmurtiya, by 187.5 percent from 1926 to 1965.[5]

The limited number of studies in which the evolution of the incidence of abortion has been traced for a sufficiently long time and over a substantial area makes it impossible to evaluate the general trend of the process more or less exhaustively.

Many studies have determined the level of the incidence of abortion at the time of the investigation in specific social groups. The incidence of official abortion fluctuates from 20 percent in the city and 18 percent in rural areas[6] to 79.2 percent[7] of the number of all artifical abortions. As some authors have indicated, 70 percent of women terminate their first pregnancies by criminal abortion in the city and 90 percent in rural areas.[8]

In some regions an increase in criminal abortions corresponding to the change in reproductive conditions is being observed, for example, in Tashkentskaya Oblast from 48.5 to 51.9 percent of all induced abortions from 1955 to 1973.[9] In other regions a decrease from 22.8 to 8.8 percent was observed from 1961 to 1965.[10]

In distinction from induced medical abortion the extent of the incidence of criminal abortion depends on the regional manifestation of the influence not only

of the factors of induced abortion in general but also of the specific factors of criminal abortion, on the social group of women being studied. In the opinion of different authors, these are the desire to conceal the very fact of pregnancy, the divulging nature of the diagnosis of "induced abortion" in the certificate for work, the long lines in the women's consultation clinics and other formalities in obtaining the operation, the desire to conceal the fact of pregnancy for the maximal period and ignorance of what period of pregnancy is critical, which leads to expiration of the 12-week period, failure to understand that criminal abortion is more harmful than medical, as a result of poor work in health instruction, etc. Accordingly, the basic specific factors of criminal abortion are the negative public attitude toward extramarital and premarital pregnancies and the negative attitude of the women themselves to the formalities in registering for the operation. This is corroborated by the relatively greater incidence of criminal abortion among middle-aged and young women, especially among unmarried women or women with unregistered marriages. It may be hypothesized that the urgency of the problem of criminal abortion will increase in connection with the current demographic trends toward increase in divorces and decrease in marriages, especially repeat ones, if the influence of the factors of abortion are not eliminated.

The problems of the incidence of induced abortion in different social groups and the dependence of abortion on socio-economic factors have received the fullest treatment in the literature. Many authors indicate that use of induced abortion as a method of intrafamily regulation of the birth rate is in reverse relation to living conditions and the level of material well-being. In fact, however, here the relation is much more complex. The process of controlling the birth rate is dictated by the complex influence of many factors, the degree of their influence being unequal. Sometimes their influence is opposite in ultimate effect. For example, there is a strong inverse relation between the level of education and the index of the child bearing function. If the process of improving housing and material well-being were accompanied by an increase in the level of education then the influence of the second factor, which is opposite in its directivity to the former, would prevail.

Moreover, in the given instance the fact of greater fertility control does not result in simultaneous increase in the level of abortions in the given social group of women. According to certain data this level will decrease because of greater use of contraceptive methods and devices.

The national-ethnic affilation of the women exerts a great influence on the level of the incidence of abortion (here the role of a national tradition of large families and to a degree the level of social development play a role). For instance, in Aginskiy Autonomous Okrug abortion terminated one-seventh of pregnancies among Buryats and one third among Russians,[11] but the inverse relationship between fertility and education in nationalities with traditions of large families is significantly higher than in Russian women. This is explained by the loss of these traditions and the low use of contaception. Some authors point out the inverse relationship between the incidence of abortion and the local provision of children's institutions.

There is a complex influence on abortion of socio-economic and

socio-psychological factors and the interrelationships between them. V. K. Kuznetsov (1970) establishes an indirect (through a tense family situation) influence on the decision to resort to abortion by the unsatisfactoriness of living and material conditions and also by alcoholism of the husband. N. A. Kravchenko and N. P. Katkova (1977) indicate that if the onset of pregnancy is accompanied by an adverse combination of such factors as poor housing conditions, low family income, a low level of the spouses' education, the woman's youth, the first years of marriage, repeated pregnancy (especially if the first ended in birth), then the risk of artificial termination of it is three times greater than with a more favorable combination of factors.

Unfortunately, there are few such studies in which the internal hierarchy of the factors of abortion and their interrrelationship are revealed.

The above indicated factors are essentially a quantitative description of the current social status of women and their standard of living. The changes which have occurred in them were caused first by change in the reproductive trend and then, in connection with the real opportunity to use abortion and also contaceptive methods and devices and reproductive behavior, to regulate the birth rate.

The popularity of contraceptive methods and devices depends on the socio-ethnic and professional composition of the group of women being studied and of the place of residence (the city or a rural area). Some combination or other of these factors is responsible for failure to use these methods and devices in 17.4-61.1 percent of cases.[12,13] Among those resorting to criminal abortion the index of nonuse is as high as 78.8 percent.[14]

The women's information on the very opportunity and method of contaception is directly proportional to the level of their education, age, duration of married life, the number of abortions obtained. In addition, in many cases it depends on the husband's desire to use contraceptive methods and devices. The overwhelming majority of investigators ascertain the prevalence of contraception that is ineffective and dangerous to the spouses' health and the unpopularity of effective and safe ones. In particular, the use rate of coitus interruptus is as high as 70 percent.[15]

The disadvantageous structure of contraceptive use is, to a considerable degree, also caused by the low quality of work in health education, the insignificant coverage of the population by it, particularly by the fact that women first receive consultations on contraception in the women's consultation clinics where they turn up in connection with the operation of induced abortion or before their first births.[16] At the same time, 66.7 percent of women have a sex life before marriage, two-thirds of women--before the age of 20, and among workers and employees 15 percent of girls--before 18.[17]

Despite the comparatively large number of publications (30 in the last 10 years) the question of complications from induced abortion remains open. The scientific value of most of the works is reduced by a number of circumstances, namely, the absence of a common classification and definitions of complications after the operation, the absence of criteria for evaluating the results of subsequent

observations, and furthermore the overwhelming majority of investigations are performed without control groups and without the use of statistical methods for determining the reliability of the results of the investigation.

In some studies which meet the requirements of statistical reliability of the results of investigation contain interesting new information. Thus, the rate of the arisal of various complications from induced abortion is not associated with the first pregnancy.[13] This refutes one of the basic postulates of health education work in this field.

Unfortunately literature on this topic is of great interest if one views it as material which enables us to study different subjective viewpoints and their influence on scientific research work in this field.

Meanwhile the question is of great scientific and practical interest, the more so since some authors consider induced abortion to be one of the factors of the increase in obstetrical pathology, prematurity and stillbirth.

Measures for preventing induced abortion essentially consist of, on one hand, shifting the emphasis in family planning to use of contraceptive methods and devices and, on the other hand, conducting a demographic policy on birth control which essentially should consist not of reproductive coercion of the family but of satisfaction of the historically and socially determined desire to have a given number of children. At the present time the existing number of children is less than the ideal in most families.

Most authors see the basic trend of this work in conducting various measures to popularize contraceptive methods and devices and optimize health education work in this field. On the basic of the experience of the socialist countries and taking into consideration the economic losses from induced abortion, some authors reccommend expanding the practice of free or partially paid distribution of contraceptives to the population. Other investigators focus attention on the different health education methods for control of induced abortion, assigning great importance to dissuading women of the necessity of this operation.

Measures for prevention of criminal abortions must consist of eliminating the various formalities in obtaining an induced abortion to the extent of creating divisions for late abortions. This, however, must be accompanied by efforts at strict implementation of the statutes on obtaining induced abort'ons, intolerence of abortionists and conducting other measures of a social and legal nature. At the same time opinion has been expressed concerning the importance of creating a negative public attitude toward abortion.

If our efforts in preventing induced and criminal abortions are based on real demographic processes, this will serve to guarantee their effectiveness.

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SOME UNRESOLVED QUESTIONS CONCERNING MEDICAL EXAMINATION OF THE RURAL POPULATION

Moscow ZDRAVOOKHRANENIYE ROSSIYSKOY FEDERATSII No 9, 1980 pp 34-37

[Article by Yu. L. Zabin, candidate of medical sciences, RSFSR Ministry of Health, Moscow]

[Text] The decree of the CPSU Central Committee and the USSR Council of Ministers "On Measures for Further Improving the National Public Health" calls for improving the forms and methods of the activities of the public health organs and institutions, among which prophylactic medical examination has an important place.

The process of introducing prophylactic medical examination to the activities of the rural treatment and prophylaxis centers comprises several stages.

After the first experiment with prophylactic medical examination of rural residents, undertaken by the medical workers of Chudnovskiy Rayon, Zhitomirskaya Oblast, and UkSSR, republic conferences were held in the Russian Federation. Such a conference took place in Tambov in 1952, in Kursk in 1954, and an out-of-town session of the USSR Academy of Medical Sciences Presidium in Krasnoyarsk in 1954. To a considerable degree these conferences determined the course of the introduction of prophylactic medical examination to the rural treatment and prophylaxis institutions of Russia. Several methodical errors were tolerated at this stage, however. In particular, it was proposed to begin work on prophylactic medical examination with a systematic investigation of collective farm workers who were not working because of illness. This would inevitably have nullified the operating principle of prophylactic medical examination. The problem of the fitness for work of the patients examined was incorrectly solved through regional commissions. Such an approach essentially eliminated the district hospital physicians from this work. Attempts were made to begin prophylactic examination of the population without the necessary critical evaluation of the status of the material and technical base of the treatment and prophylaxis institutions and personnel resources. This was essentially substituting their record-keeping for dispensary measures.

The next stage in the introduction of prophylactic medical examination called for expanding the continent of patients examined by each highly specialized department. In connection with this the center of gravity of dispensary work shifted, as it were, from the district hospital to the regional ones.

Thus, the results of special investigations conducted during those years showed that 82.2 percent of patients examined from the rural region of Orlovskaya Oblast (1974) were observed by physicians of the cental hospital and only 17.8 percent were under the observation of the district hospital physicians. Although the physicians of the highly specialized departments began to be drawn into prophylactic medical examination, the major role in carrying out this measure in rural areas was played, as before, by the internists (during this period 41.7 percent of the patients examined were observed by internists.)

The current stage of prophylactic medical examination may be characterized as transitional from examination of individual contingents to mass examination of the rural population.

In their investigations I. D. Bogatyrev, L. G. Lukarev, and S. Ya. Freydlin created a theoretical base on which prophylactic examination of the urban and rural population should be built at the present stage and in future. Up to now, however, there have been a number of unsolved problems in the methods of organization of the rural population.

The goal of switching to general prophylactic examinations creates the necessity of constantly increasing the number of contingents observed by each physician performing prophylactic examination of the population. Practice has already shown, however, that only for some internists does the number of patients examined correspond to the accepted reference norms and that for physicians of other specialties the number of patients examined as a rule is not even as high as 100. According to our data, each physician who took part in prophylactic examination had 72 patients under observation on the average.

Accordingly, at present there is a real opportunity to ensure a certain increase in the scope of prophylactic observation of the population by increasing the number of patients observed by each physician.

As universal prophylactic examination is introduced the number of contingents examined will grow in an increasingly complex manner This requires the identification of concrete measures which anticipate stable growth rates for the contingents examined. Considering that the district hospital internist must observe every resident of his district in the course of prophylactic examination, with an increase in the number of patients observed by the physicians of highly specialized departments the indirect load of the district hospital physicians will increase still further. If prophylactic examination of patients by particular specialties is completely entrusted to the appropriate specialists alone, then the danger emerges that a situation will arise in which the physician examines not the patient but the disease.

During the process of dynamic observation, while creating the resources for

handling patients receiving prophylactic examinations in outpatient and inpatient care it must not be forgotten that prophylactic examination is a profoundly social problem. In connection with this, increasingly greater significance must be assigned to the implementation of social measures for disease prevention. Even with a substantial increase in the role of the sanitary and epidemiological service in carrying them out, particularly in solving domestic problems, the district hospital physician must remain the leading figure. To take the path of reducing the scope of social measures of prophylaxis means substituting specialized treatment of registered patients for prophylactic examination.

The ever increasing resources of medical science and practice ensure increasingly early detection of the incipient forms of pathological changes or functional deviations from the norm in the human organism. This in turn assumes that persons in the stage of premorbid conditions are placed under observation in an increasingly active manner. All this also increases the load of the district internist in providing prophylactic examination of the population.

In connection with the socio-economic transformations occurring rurally, concentration of rural residents in large settlements is taking place, and this in turn is making it necessary to reduce the number of district hospitals.

According to A. G. Safonov's information, 1364 rural district hospitals were reorganized in 1970-1975; of them only 71.2 percent were converted into outpatient clinics. The remaining hospitals were reshaped into paramedical obstetrical centers or closed, i.e., the previously existing rural districts were eliminated and, accordingly the number of district hospital physicians conducting prophylactic examination of the population was in fact reduced.

Thus a certain segment of rural residents, having gained, to be sure, opportunities of receiving specialized medical care, "lost" their district physicians who coordinated and directed the activities of all physicians in their district and implemented the socio-hygienic measures which are so important in prophylactic examination.

A no less complex situation connected with the increase in the number of patients being examined also arises for the physicians of highly specialized departments, since their numbers in rural treatment and prophylaxis institutions are considerably smaller than that of internists, and subsequent growth of the number of their staff appointments is not envisaged.

The organization of outpatient polyclinic care rurally on the district principle as in the cities may prove unsuitable in the given case.

At the present stage the necessity of creating scientifically valid methodologies and norms for dispensary work is increasing. Substantial reserves in ensuring a constant increase in the contingents of patients examined may be the systematic introduction of elements of scientific organization of labor in all subdivisions of the medical and sanitary services of the rural area, and in more distant prospect, the systematic introduction of modern achievements in electronics and medical and computer technology which ensure the creation of information retrieval systems and, in future, of automated systems of control for

prophylactic examination.

The problem of training district hospital physicians and, when district service is organized rurally, district physicians of reorganized districts, is also a burning issue.

Prophylactic examination of healthy contingents in rural areas has long been traditional. Usually it amounts to conducting periodical medical examinations. Measures ensuring purposeful prophylaxis of diseases and improvement of the physical development of people's health are not always applied.

It should be noted that up to the present the problems of the methods of performing different types of medical examinations have still not been solved. There is no clarity even in examination terminology.

The absence of clear regulation complicates the work of the practical physicians and makes comparison of the data obtained difficult. Apparently it is necessary to accept a single classification of examinations, unify them under the collective title of "prophylactic medical examinations" and subdivide them into preliminary (for starting work), periodical and special. The existence of other terminology must be recognized as unadvisable.

The isolated performance of different types of special examinations by individual sevices, dispensaries and other institutions is scarcely rational. Special examinations should be performed simultaneously and, as far as possible, combined with periodical examinations. It is important that both the procedure of conducting examinations itself and the methods of laboratory and instrumental investigation in use be as little burdensome as possible for the person examined.

Mobile outpatient clinics mounted on the chassis of vehicles with a high capacity for cross-country travel in which teams of physicians of different specialities work may be used in conducting periodical examinations in rural areas. Such outpatient clinics should be equipped with X-ray, fluorographic equipment and apparatus for functional diagnostics. Radio stations for communications with the regional hospital should be installed in such mobile outpatient clinics. The data obtained may be transmitted to the central regional hospital via the long-distance communications system for automated machine analysis. The district physician should organize such examinations and participate in them directly.

Under the conditions of rural areas, with the switch to universal prophylactic medical examination of the population the role of the average medical worker as the physician's helper should increase still further. Along with work on the organization and performance of prophylactic examinations he should also be given the performance of certain manipulations (measuring ocular pressure, taking EKG's, determining arterial pressure, etc.) and also the performance of operations to draw up medical records and preparing them for machine processing.

Every person under prophylactic observation must become a more aware and active participant. The different forms of medical education and particularly training of the population in hygiene must play a significant role in this process.

Medical workers must do more active work in explaining the essence of prophylactic medical examination and popularizing socio-economic achievements among the directors of farms and different enterprises. The success of universal prophylactic examination and its effectiveness will also depend on the attitude of the physicians themselves and the average medical workers toward this measure, their psychological orientation, theoretical and practical preparation for performing the indicated work. In this connection, the molding of an inner conviction of the significance of universal prophylactic examination in medical workers must be considered one of the most important tasks.

Only on the basis of the existing advantages of the socialist system, with an adequate material-technical base for public health and with the successful solution of personnel problems is full-fledged solution of the problems of universal prophylactic examination of the population possible. Early detection of diseases, predominantly at the stage of premorbid conditions, must be made the basis of prophylactic examination. Important divisions are ensuring regular dynamic observation of patients, organizing a wide range of sanitary-prophylactic and socio-sanitation measures, automating of individual elements of prophylactic examination, ensuring a conscious attitude on the part of the patients toward its performance, and fostering a firm conviction of the necessity of performing it on the part of medical workers.

[9144/0234 - 9180]

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RESEARCHING MULTIPLE CAUSES OF DEATH

Moscow ZDRAVOOKHRANENIYE ROSSIYSKOY FEDERATSII in Russian No 9, 1980 pp 22-27

[Article by V. I. Dmitriyev and A. V. Nikhol'skiy, candidates of science, Republican Scientific Research Laboratory for Medical Demography (director, Professor N. S. Bednyy), Moscow Scientific Research Institute of Epidemiology and Microbiology, RSFSR Ministry of Health]

[Text] Analysis of multiple causes of death has an important place among the methods of studying the death rate of a population. It is well known that most deaths are not the result of a single cause but of a complex of interrelated diseases. Thus, a single disease listed in the physician's death certificate as the underlying cause does not reflect all pathological processes which caused the death. In recent years along with a trend toward improvement of the quality of selection of a sole cause of death, the inadequacy of the very principle of selecting a single cause of death has been observed. It must be noted that "multiple causes of death" is often understood to mean only cases of competing causes of death, i.e., cases which cause difficulty in selecting a single disease as the underlying cause of death. In international practice the concept of multiple causes of death includes the underlying cause of death, complications and contributing causes or diseases.

This article presents the results of analysis of physician's death certificates issued in one of the average cities outside the chernozem belt in connection with death from disease of the circulatory system. In 90.2 percent of cases these data were supplemented with materials from the original medical records and physician's certificates issued in connection with death from other causes, but only for dead who either died in the hospital or underwent pathoanatomical examination there. This is due to the fact that death certificates not related to cardiovascular pathologies were not supplemented with materials from the original medical records, a fact which made it impossible to verify the accuracy and completeness of these physician's certificates. In order to study multiple causes of death, certificates issued by hospital physicians, pathoanatomists and medicolegal experts were used.

In order to ensure the comparability of the results with official materials on the causes of death, the existing rules on selection of the underlying disease

and other diagnostic terms (complications and causes contributing to death) were coded independently of each other. In coding cases of death from malignant neoplasms we selected only the initial localization.

The number of certificates with multiple causes of death (certificates in which secondary conditions were indicated in addition to the underlying cause) was 85.6 percent.

The proportion of death certificates with multiple causes of death depends on a whole series of factors, primarily on the quality and completeness of the death certificates. The age composition of the deaths is a no less important factor influencing the frequency of multiple causes of death. It has been established that with an increase in the age of the dead the number of physician's certificates with multiple causes of death increases and the proportion of certificates with a single cause of death decreases accordingly. Moreover, the proportion of certificates with multiple causes of death also depends on the composition of the causes of death. It has been established that most underlying causes of death are listed in conjunction with complications and contributing diseases and also with both together. These are basically chronic long-term diseases which lead to death as the result of the development of fatal complications or the addition to them of another chronic disease contributing to the fatal outcome.

The relative significance of certificates with single causes of death was 14.4 percent. Among these were cases in which listing one cause exhausts all circumstances of the death (acute diseases and accidents, poisonings and trauma). A number of malignant neoplasms were recorded among single causes of death. The fact is that according to the coding rules in cases of death from this kind of pathology only the initial localization is coded when metastases are present. Consequently, in the absence of other complications and contributing diseases these cases are classified with examinations with a single cause of death. A single cause of death was indicated in certificates for deaths from accidents, poisonings and trauma in 67.1 percent, from malignant neoplasms, in 27.4 percent and from other diseases, in 21.6 percent.

Multiple causes of death were characterized by the presence of complications or contributing diseases. Here it should be noted that the frequency of recording complications and contributing diseases depended on the basic disease. Fewer complications were recorded for deaths from accidents, poisonings, trauma and infectious diseases. The number of complications was also insignificant in deaths from malignant neoplasms, a fact which is explained by the coding rules, as already indicated. Chronic diseases such as disease of the circulatory system, respiratory organs, genitourinary system and digestive organs result in death through complications as a rule.

The distribution of deaths from multiple causes with respect to the number of secondary diagnostic terms demonstrated that in 39.3 percent of the cases two other conditions were indicated in addition to the underlying disease; somewhat less often, one (36.3 percent). Three terms were recorded in 15.5 cases; four in 7.5 percent; 5 or more, in 1.2 percent. The number of diagnostic terms secondary to the underlying disease also depended on the underlying cause of

death. A single secondary condition was most often recorded in deaths from accidents, poisonings and trauma (85.3 percent), disease of the arteries, arterioles and capillaries (62.8 percent), malignant neoplasms (56.7 percent) and hypertensive disease (52.8 percent). Five or more secondary diagnoses were noted in deaths from diseases of the genitourinary system (9.8 percent), rheumatism (5.7 percent) and diseases of the digestive organs (3.4 percent; table 1).

Contributing diseases were most frequently recorded in deaths from venous thromboses and embolisms (100 percent), vascular lesions of the brain (76.2 percent) and myocardial infarct (61.8 percent). Of all (9890) encoded diagnostic terms 37.1 percent were encoded as the underlying cause of death; 26.4, as complications; 36.5, as contributing causes of death (table 2).

According to the data obtained, certain diseases are most often indicated as the basic cause of death and very seldom as a complication or contributing disease. Thus, diagnoses of malignant neoplasms are recorded as the underlying causes of death in 90.8 percent of cases; myocardial infarct, only as the underlying disease; accidents, poisonings and trauma are underlying causes of death in 96. percent of cases; rheumatism in 91 percent; ischemic heart disease , in 82.7 percent. There are diseases which are seldom the underlying cause of death and which contribute to the fatal outcome significantly more often than the underlying disease. Among these are, for example, hypertonic disease, which is indicated as a contributing disease in 87.7 percent of cases, chronic nonspecific pulmonary disease (recorded as contributing in 71.0 percent of cases).

Many diseases (disease of the digestive organs, genitourinary system and circulation) are recorded to a practically identical extent both as the underlying cause of death and as a contributing disease.

The group of other diseases, which includes d'sease of the endocrine glands, metabolic diseases, mental disorders and alcoholism, diseases of the bones and joints and certain other diseases, is more often given as contributing diseases.

The composition of complications and contributing diseases differs from that of underlying causes of death. When deaths are distributed by underlying disease, disease of the circulatory system (65.0 percent), accidents (1.5 percent) and malignant neoplasms (6.2 percent) are of greatest importance. This amounts to a total of 88.7 percent of all cases of death from underlying diseases.

Among causes contributing to death first place belongs to disease of the circulatory system (60.1 percent). In second place are other diseases (18.3 percent); disease of the respiratory organs takes third place (15.9 percent). The share of malignant neoplasms and accidents, poisonings and trauma in the composition of contributing causes of death is very small (0.6 percent each).

Complications differ sharply from underlying and contributing diseases in composition (table 3). Despite the fact that diseases of the circulatory system comprise the majority of all complications (83.8 percent), their composition differs from that of underlying causes of death and diseases contributing to death.

Table 1. The Distribution of Deaths from Multiple Causes of Death in Terms the Number of Secondary Diagnostic Terms (As Percentage of the Number of Deaths from a Specific Cause)

Cause of Death	Number of Findings On Death With Secondary Diagnostic Terms				
	1	2	3	4	5
Infectious and Parasitic Diseases	50.0	34.0	10.1	4.0	2.0
Malignant Neoplasms	36.7	50.5	4.9	6.7	1.2
Disease of the Circulatory System	29.2	43.5	18.0	8.4	0.9
Rheumatism	7.0	54.9	22.5	9.9	5.7
Hypertensive disease	52.8	41.8	1.8	1.8	1.8
Ischemic cardiac disease	29.8	38.4	19.8	11.8	0.2
Myocardial infarct	23.1	33.9	23.0	18.8	1.2
Vascular lesions of the brain	21.4	56.9	17.7	4.7	1.3
Disease of the arteries, arterioles and capillaries	62.8	22.1	9.9	4.1	1.1
Venous thromboses and embolisms	14.3	57.1	28.6	--	--
Disease of the Respiratory Organs	43.2	33.5	14.8	5.2	3.3
Including chronic nonspecific pulmonary disease	38.3	36.2	18.1	4.3	3.1
Disease of the Digestive Organs	40.4	36.0	11.2	9.0	3.4
Disease of the Genitourinary System	38.7	16.1	22.5	12.9	9.8
Accidents, Poisonings and Trauma	85.3	13.7	1.0	--	--
Other Diseases	51.7	36.2	6.9	3.4	1.8
All Causes	36.3	39.5	15.5	7.5	1.2

Table 2. The Distribution of All Diseases As Underlying Causes of Death, Complications and Contributing Causes (As Percentage of the Total Number of Specific Conditions)

Cause of Death	Disease		
	Underlying	Complication	Contributing Cause
Infectious and Parasitic Diseases	73.3	10.7	16.0
Malignant Neoplasms	90.8	--	9.2
Disease of the Circulatory System	35.4	32.2	32.4
Rheumatism	91.0	--	9.0
Hypertensive disease	10.2	2.1	87.7
Ischemic cardiac disease	82.7	0.2	17.1
Myocardial infarct	100.0	--	--
Vascular lesions of the brain	69.0	18.5	12.5
Disease of the arteries, arterioles and capillaries	18.5	18.1	63.4
Venous thromboses and embolisms	35.0	50.0	15.0
Disease of the Respiratory Organs	17.5	20.3	62.2
Including chronic nonspecific pulmonary disease	26.1	2.9	71.0
Disease of the Digestive Organs	30.9	36.3	32.8
Disease of the Genitourinary System	22.3	41.0	36.7
Accidents, Poisonings and Trauma	96.7	--	3.3
Other Diseases	9.4	7.2	83.4
All Causes	37.1	26.4	36.5

Table 3. The Composition of Underlying Causes of Death, Complications and Contributing Diseases (As Percentage of Total)

Cause of Death	Disease			All conditions
	Underlying	Complication	Contributing	
Infectious and Parasitic Diseases	1.5	0.3	0.3	0.8
Malignant Neoplasms	6.2	--	0.6	2.5
Disease of the Circulatory System	65.0	83.8	60.1	68.2
Rheumatism	2.0	--	0.2	0.8
Hypertensive disease	1.5	0.4	13.1	5.4
Ischemic cardiac disease	34.0	0.1	7.1	15.3
Myocardial infarct	4.5	--	--	1.7
Vascular lesions of the brain	22.4	8.4	9.6	12.0
Disease of the arteries, arterioles and capillaries	4.7	6.5	16.4	9.4
Venous thromboses	0.2	0.4	0.1	0.2
Disease of the Respiratory Organs	4.4	7.2	15.9	9.3
Including chronic nonspecific pulmonary disease	2.6	0.4	7.5	3.8
Disease of the Digestive Organs	2.6	4.3	2.8	3.1
Disease of the Genitourinary System	0.8	2.2	1.4	1.4
Accidents, Poisonings and Trauma	17.5	--	0.6	6.7
Other Diseases	2.0	2.2	18.3	8.0

While ischemic heart disease and vascular lesions of the brain have the greatest relative significance among the former, among complications it belongs to the group of other diseases of the cardiovascular system, which includes acute and chronic cardiovascular insufficiency, disturbances of rhythm and conduction, etc.

Of course, malignant neoplasms, rheumatism, myocardial infarction accidents, poisoning and trauma are not encountered among complications. A very small proportion of complications belongs to ischemic heart disease (0.1 percent) and infectious diseases (0.3 percent). Comparison of the two distributions of deaths in terms of the underlying cause of death and all recorded conditions makes it possible to determine the advisability of analyses of multiple causes of death and demonstrates what supplementary diagnostic diseases secondary conditions may add to causes of death.

When all recorded conditions are taken into consideration in the composition of causes of death the proportion of diseases of the circulatory system increases from 65 to 68.2 percent (chiefly because of complications among which the main role belongs to the group of other diseases of the cardiovascular system); disease of the respiratory organs, from 4.4 to 9.3 percent (because of contributing diseases, among which first place belongs to chronic nonspecific pulmonary disease), disease of the digestive organs, from 2.6 to 9.3 percent (because of complications); disease of the genitourinary system, from 0.8 to 1.4 percent and other diseases from 2 to 8 percent.

When all recorded conditions were taken into consideration the relative significance of malignant neoplasms, accidents, poisonings and trauma and of infectious and parasitic diseases decreased.

Of great significance in the study of multiple causes of death is detection of the most important, most often encountered combinations of underlying causes of death with complications and contributing diseases. Analysis of the basic causes of death (disease of the circulatory system, malignant neoplasms and diseases of the respiratory organs) made it possible to detect their most frequent complications and contributing diseases.

In all, in deaths from disease of the circulatory system, 4406 secondary conditions were recorded, including 62.3 complications and 37.7 percent contributing diseases. Among complications leading or contributing to death in disease of the circulatory system, complications belonging to the group of cardiovascular diseases were encountered most frequently (87.6 percent). Complications associated with pathological changes taking place in other organs and systems were recorded significantly often. Thus, diseases of the respiratory organs which are complications of disease of the circulatory system were noted in 7.2 percent of cases; disease of the digestive organs, in 0.8 percent; disease of the genitourinary system, in 0.3 percent and other diseases, in 4.1 percent.

Among complications belonging to the group of diseases of the circulatory system, acute and chronic cardiovascular insufficiency comprise the majority (63.6 percent). Cerebral hemorrhages are in second place (10.1 percent); next come cerebral thromboses (5.1 percent), cardiac fibrillation (4.4 percent);

thrombosis of the coronary arteries (3.1 percent), pulmonary heart (2.7 percent), thrombosis of the femoral artery, with subsequent gangrene of the lower extremities (2.8 percent), softening of the brain (1.9 percent), cardiorrhexis (1.8 percent), thrombosis of the mesenterial vessels with subsequent gangrene of the intestine (1.6 percent), thromboembolism of the pulmonary artery (1.2 percent) and other complications (1.7 percent).

Study of the basic disease with the contributing diseases which intensify its course to a significant degree is of important practical significance. First place among contributing diseases in deaths from cardiovascular pathology belongs to disease of the circulatory system (73.2 percent); second, to disease of the respiratory organs (14.0 percent); third, to other diseases (5.1 percent). Next come diseases of the digestive organs (3.4 percent), genitourinary system (1.9 percent), accidents, poisonings and trauma (1.2 percent), malignant neoplasms (1.0 percent) and, finally, infectious and parasitic diseases (0.2 percent). In the class of diseases of the circulatory system, disease of the arteries, arterioles and capillaries is often encountered (41.8 percent), hypertonic disease (34.4 percent), ischemic heart disease (14.3 percent), and vascular lesions of the brain (9.1 percent). It should be noted that death from ischemic heart disease often is promoted by lesions of the brain and conversely, death from vascular lesions of the brain, by ischemic heart disease.

In deaths from malignant neoplasms 74.5 percent complications and 25.5 percent contributing diseases were recorded. Cancerous cachexia and intoxication has an important place in the structure of complications in deaths from malignant neoplasms (in 57.4 percent); pulmonary-cardiac insufficiency (in 17.8 percent) and chronic cardiovascular insufficiency (in 8.4 percent). Among other complications brain edema, peritonitis and hemorrhages are most often encountered. Ischemic heart disease (33.3 percent) and arteriosclerosis and its manifestations (15.9 percent) have an important place in the structure of diseases contributing to death from malignant neoplasms. Disease of the respiratory organs contributed to death in 6.2 percent of cases.

In deaths from disease of the respiratory organs 7.14 percent complications and 28.6 percent contributing diseases were recorded. Among complications, an important place belongs to acute and chronic pulmonary-cardiac and cardiopulmonary insufficiency (76.4 percent). In 16.4 percent of cases of death from disease of the respiratory organs other complications contribute.

Of greatest significance in the structure of contributing causes is ischemic heart disease (58.2 percent of all contributing diseases).

Thus, the results of study of multiple causes of death showed that analysis of them gives valuable information supplementary to the official materials on the causes of death, and promotes detection of the most important and most frequently encountered combinations of an underlying disease with complications and contributing diseases.

[8144/0233 - 9380]

UDC 614.1:312](049.32)

NEW BOOK OUTLINES PLACE, SUBJECT MATTER OF MEDICAL DEMOGRAPHY

Moscow SOVETSKAYA MEDITSINA in Russian No 10, 1980 pp 122-123

[Review by S. Ya. Freydlin of the book "Mediko-demograficheskoye izucheniye naseleniya" (Medical-Demographic Population Analysis) by M. S. Bednyy, Moscow, Izdatel'stvo "Statistika", 1979, 224 pages]

[Text] This book is devoted to the pressing problems of medical demography. Chapter 1 describes the content of demography and its intimate relationship with social hygiene, and it critically evaluates the extreme sociologization of demography. We can agree with the author's opinion that medical demography, being a science intermediate between medicine and demography, must be included within the composition of social hygiene, organizing public health as a science and a subject of instruction. The author sees no grounds for the assertion that public health organization does not have its own subject of research, and he emphasizes that "the rural physician must know how to give advice and take a part in questions concerning marriage and family matters, general and medical-hygienic education, sex education, sensible job placement following illness, and the work-rest schedule--that is, he must provide not only therapeutic but also medical-social care."

This chapter also presents the problem of medical geography--studying the population's health and ability to work. The population's aging process, observed in recent years, is known to reflect itself mainly on the size of the economically active population. At the same time it has been persuasively demonstrated that we are not making adequate use of the labor of the elderly. Analysis of their health and ability to work requires considerable effort and resources. The author validly cites, as the main difficulty, absence of objective and persuasive criteria to serve as indicators of the effectiveness of public health. The formal approach to studying the so-called economic effectiveness of public health (reduced incidence of certain diseases, a decrease in morbidity involving temporary incapacitation, and so on) is criticized with full grounds.

Chapter 2 illuminates the state of health in the modern world. The criteria of health are described. In addition to the traditional demographic indicators, a new direction is described--potential demography. Changes in birth rate, life span, and causes of death are examined. Trends in child mortality in different countries are described.

Chapter 3 is devoted to health trends in the USSR. It presents the basic laws governing the present dynamics of some indicators: birth rate, death rate, and average life span. The chapter ends with a discussion of a highly important issue--

the factors responsible for differences in the life spans of men and women. That women have a longer life span is substantiated, and the ways for correcting the inconsistency are examined.

Chapter 4 describes the results of research on population morbidity. Imperfections in the method for studying general population morbidity are subjected to sharp criticism. This method is one of meaningless statistics, requiring nothing more than classifying primary diagnoses and tabulating hospital visits. The author asserts "...that general morbidity statistics based on visitation frequency do not and cannot have analytical, scientific significance" (p 157). This is a long-running debate, and the proponents of this method are becoming increasingly fewer in number.

A special section is devoted to morbidity studies on individual occupational groups.

A section on morbidity prognosis raises some argument. The author feels that it is rather difficult to predict morbidity. We should add to this that it is also hardly possible to do so.

The section "Heart Diseases as a Medical-Demographic Problem" presents sources of information dealing with heart diseases and the demographic aspect of cardiovascular pathology.

The book is written knowledgeably, and in good language. It will be read with interest by public health physicians and organizers.

[71-11004]

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CSO: 1640

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MONOGRAPH CONTRIBUTES TO URBAN PUBLIC HEALTH ANALYSIS, PLANNING

Moscow SOVETSKAYA MEDITSINA in Russian No 10, 1980 p 123

[Review by A. V. Nikol'skiy of the book "Zdravookhraneniye krupnogo sotsialisticheskogo goroda" (Public Health in a Large Socialist City) by V. A. Minyayev and I. V. Polyakov, Moscow, Izdatel'stvo "Meditsina", 1979, 320 pages]

[Text] This monograph by V. A. Minyayev and I. V. Polyakov is devoted to research on the processes, trends, and the sociohygienic and demographic problems of urbanization. Scientifically founded long-range planning of therapeutic-preventive care is impossible today without detailed analysis of public health trends and forecasts. The mutual relationship established between the health's public and development of medical care must be based on an assessment of a system of public health statistics. However, not enough has been done yet to arrive at a scientific solution to this highly important and pressing problem. This monograph is a step forward in the direction of scientifically substantiating long-range public health planning in the country.

The monograph is distinguished by a comprehensive sociohygienic approach to different problems in medicine and public health. It contains not only theoretical premises, but also well-grounded practical conclusions which the author arrives at on the basis of a detailed analysis and generalization of the facts, and study of the vast literature. Of interest is the integrated, multifaceted nature of the analysis: the combination of historic, sociohygienic, and demographic analysis, establishment of an organic mutual relationship between past and present phenomena, and the orientation toward improving the forms and methods of organizing medical care in the future.

The mutual relationships between the health of the public and the developmental level of public health are analyzed by the authors on the basis of extensive statistics on Leningrad. Being a superlarge city, Leningrad is in a sense a model of future society, and the analysis performed by the authors has great significance not only to Leningrad but also to the country as a whole.

The book devotes much attention to the sociohygienic aspects of demographic processes and to forecasting. It examines the influence of urbanization on the birth rate and its dynamics. Discussing the birth rate, the authors indicate the decreasing trend it has experienced in recent years, and the general decline in birth rate dynamics. The decrease in birth rate can be explained, in the opinion of the authors, by the aggregate influence of factors such as change in the age and sex structure of the

population, reduction of the number of women of child-bearing age and persons of marrying age, a drop in child mortality, a rise in participation of women in social production, and so on. The influence of the intricate complex of demographic and sociohygienic factors, including urbanization processes, is emphasized concurrently.

The book contains extensive statistics on morbidity, disability, and mortality, and it deeply analyzes mortality structure in relation to causes. For the first time in domestic literature a multifactorial model of urban morbidity is built, the methods for developing therapeutic-preventive care for the public of a large city are developed, and this development is forecasted. Much attention is devoted to pressing medical and sanitary problems of public health, associated in particular with the need for determining the demand for medical care in a time of increasing urbanization, for real planning of the public's demand for medical care, for improving the quality of medical services, and for comprehensively implementing the prevention principle.

Integrated analysis of the public's health, revelation and consideration of its trends, and substantiation of scientific forecasts permitted the authors to submit a number of key proposals on improving the public health service (sensible use of bed space and personnel, introduction of the elements of scientific organization of labor into the work of polyclinics and hospitals), and to substantiate the prospects of its subsequent development.

The monograph's shortcomings include the wealth of examples in some areas contrasted with superficial examination of some other areas, particularly the demand for specialized medical care. Relatively little space is devoted to analysis of the influence of demographic factors on child mortality (for example the number of the child in the family, the age structure of women in childbirth, and so on). However, these shortcomings do not reduce the book's theoretical and practical value.

This monograph is current, and it has doubtless theoretical and practical significance. It contains a large number of facts, interesting ideas are suggested, it is well illustrated with tables and figures, and it reads easily. The book may be highly useful to social hygienists, public health organizers, and demographers.

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CURRENT TRENDS IN DEVELOPMENT OF RADIOPROTECTIVE AGENTS (LITERATURE SURVEY)

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[Article by V. G. Vladimirov and T. G. Zaytseva]

[Text] It is primarily the fact that the known radioprotective agents either have insufficient radioprotective efficacy or induce development of a number of toxic or side effects when given in the recommended doses that prevent the wide use of radioprotective agents in medicine. Current conceptions of the mechanisms of radioprotective action and assessment of prospects for synthesizing new radioprotective agents leads to the conclusion that one could hardly expect to develop an agent in the near future that would meet all the requirements of clinical medicine. Development of radioprotective formulas appears to be a more realistic route toward the above goal. At the present time, development of such formulas could be based on two principles. One of them consists of the fact that improvement of tolerance of radioprotective agents is achieved by the joint use of certain pharmacological agents that prevent development of side-effects or attenuate them. The other principle is based on consideration of the differences in mechanism of action of different radioprotective agents. Combinations of drugs are so chosen as to have the radioprotective action thereof added or enhanced. This makes it possible to prevent manifestations of toxicity with the use of lower doses of radioprotective agents, known to be well-tolerated, in some cases and, in others, to obtain a protective effect that is substantially greater than is observed with the use of each agent individually, even when given in maximum tolerated dosage.

Evidently, combined prescriptions based on several radioprotective agents [RPA] with different mechanisms of action will be the best, with inclusion of drugs that correct their pharmacological activity.

Almost 10 years have passed since the analytical survey of M. V. Vasin et al. (1970) was published, which dealt with development of radioprotective formulas. This period was characterized by further accumulation of facts and better knowledge about the mechanism of RPA and complexes thereof. In addition, new products have been found in recent years, and this opens up the possibility of developing more effective radioprotective formulas on

their basis. For this reason, the following question appears to have validity: what are the current trends in development of radioprotective formulas, and have basically new views appeared about this problem?

Our objective here was to try to give an answer to this question. Even a cursory look through the relevant literature indicates that sulfur-containing RPA (cystamine, AET,* cystaphos and others) still constitute the majority of radioprotective formulas. Most often, products from the class of indolyl alkylamines are used as another component, and their mechanism of radioprotective action is basically different from that of sulfur-containing compounds. The high radioprotective activity of cystamine (cysteamine), AET or cystaphos, when given together with indolyl alkylamines, has been known for a long time (L. P. Semenov, 1964, 1968; I. B. Bynkovskaya and A. V. Bogatyrev, 1965; P..G. Zherebchenko, 1964, and others). It can also be considered firmly established that the synergism of radioprotective action of these RPA is related to more effective protection of radiosensitive tissues (S. P. Yarmonenko and G. M. Ayrapetyan, 1966; Maisin and Lambiet-Collier, 1967a, b; Maisin et al., 1968). Nevertheless, many aspects of the action of such formulas remain unstudied to date, particularly questions related to optimization of proportions of components and parameters of protection in the case of exposure to superlethal doses of radiation. According to Dostal (1969), Dostal and Menkl (1971), combined administration of cystamine and mexamine provides virtually 100% protection of mice exposed to doses in the range of 900 to 1100 R, and to obtain over 50% animal survival when exposed to a dose of 1300 R. Using the method of isobolic diagrams for analysis of radioprotective and toxic action of RPA, these authors were able to demonstrate the nature of change in toxicity and protective effect of the prescription as a function of the proportion of products used in it. In all variants of experiments, synergism of radioprotective effect of RPA was obtained; at the same time, such unidirectional action was absent with respect to toxicity. Thus, if there is prevalence of cystamine in the combination one observes lower toxicity (i.e., manifestation of antagonism in action of the products), while with increase in dosage of mexamine the toxicity of the mixture increases.

L. P. Semenov et al. (1972) demonstrated that it is possible to provide protection against superlethal doses of radiation with the combined use of cystaphos (340 mg/kg) and mexamine (50 mg/kg). Preventive administration of this complex to mice prior to exposure to 1050-1100 R radiation protected 35-50% of the animals. Addition to this complex of sodium nitrite enhanced its efficacy even more, and in a number of cases resulted in up to 70% animal survival, even when the products were given by mouth. Many radiobiologists have studied the protective action of a combination of AET and indolyl alkylamines (P. G. Zherebchenko, 1964; S. P. Yarmonenko, 1965; Wang and Kerejakes, 1962, and others). The opinion has been voiced that

*Aminoethylisothiuronium

the radioprotective action of the above products is enhanced when they are given in combination (I. G. Krasnykh et al., 1962; S. P. Yarmonenko, 1965). Thus, survival constituted at least 60% among mice exposed to 1100 R radiation and given mexamine preventively in a dosage of 75 mg/kg with AET in a dosage of 50 mg/kg, whereas separate use of this agents resulted in survival of only 25% at best. FUD [dose reduction factor], calculated according to $LD_{50/30}$, rose from 1.5 to 1.8 (S. P. Yarmonenko, 1965). A. V. Ziya et al. (1973), Santha et al. (1972) made more comprehensive studies of the efficacy of a complex consisting of mexamine and AET used in different doses. According to their results, at least two conclusions can be derived. In the first place, they confirm data pertaining to the high radioprotective activity of this complex (70-90% survival of experimental mice) with substantial reduction of dosage of these agents, as compared to the optimum radioprotective levels (up to 40 mg/kg for AET and 10 mg/kg for mexamine), which should unquestionably be considered the result of enhancement of the radioprotective action of the agents (Santha et al., 1972). In the second place, there was demonstration of the possibility of obtaining a high protective effect (up to 70% survival of irradiated mice) when the RPA are given by mouth (A. V. Ziya et al., 1973), a circumstance that is of extreme importance, from the standpoint of clinical medicine. However, by far not all sulfur-containing agents have the capacity to enhance the radioprotective action of indolyl alkylamines. In particular, the combined use of etiron and mexamine (P. G. Zherebchenko et al., 1968), does not demonstrate this effect, and in the authors' opinion this is related to the unidirectional effect of both agents on the cardiovascular system.

Maximum radioprotective activity was observed in a complex with three components: mexamine + AET + cystaphos (P. P. Lyarskiy et al., 1970). In this case, virtually 100% survival of mice was obtained, even when they were exposed to 1200 R radiation. A mixture of AET (50 mg/kg), cystaphos (150 mg/kg) and mexamine (5 mg/kg) provided good protection for animals over a significant range of radiation doses, from 1100 to 1700 R. The same agents, but used in somewhat different proportions (25 mg/kg AET, 25 mg/kg mexamine and 175 mg/kg cystaphos) also presented high protective activity (S. P. Yarmonenko, 1969). T. N. Pugacheva et al. (1972, 1973) made a more detailed study of the formula for such a complex. It was established that high radioprotective activity was retained, even when the dosage of cystaphos was reduced to 150 mg/kg and mexamine to 4 mg/kg. A comparative analysis of the radioprotective action of this complex with 1.5- and 2-fold increase in dosage of all components revealed that, in this case, one could obtain 70-80% survival of mice, even with exposure to supralethal doses of radiation (1700 R). A rather high efficacy of the complex was observed even when the animals were exposed to 2000 R. A parallel study of toxicity of the complex made it possible to determine its optimum variant (6.2 mg/kg mexamine, 37.5 mg/kg AET and 225 mg/kg cystaphos) with a range of therapeutic action of about 2. Apparently, we can relate the possibility of enhancing the protective effect by changing the proportion of different components in the complex without

a corresponding increase in toxicity to the more favorable redistribution of sulfur-containing radioprotective agnets in the body under the influence of mexamine (L. N. Pauper et al., 1972; G. M. Ayrapetyan et al., 1969).

A formula consisting of AET, cystaphos and mexamine is, unfortunately, characterized by a rather high cumulative dose. However, if cystaphos is replaced with cystamine (Dostal, 1969), one can reduce the total dose of the prescription without altering its protective properties. For example, one can obtain 80-100% survival of mice exposed to radiation in doses of 900 to 1100 R by using the following combination: 100 mg/kg cystamine, 10 mg/kg serotonin and 20 mg/kg AET. The high efficacy of the above two- and three-component complexes is undoubtedly attributable to better conditions of protection of radiosensitive tissues and, first of all, bone marrow, as indicated by the correlation between indices of animal survival and number of myelokaryocytes in bone marrow, as well as number of endogenous colonies in the spleen (L. F. Semenov et al., 1972; P. P. Lyarskiy et al., 1970). As a rule, there was complete recovery of histological tissue of bone marrow, spleen and thymus of protected animals by the 30th postradiation day, although normalization of lymph nodes and Peyer's patches had not occurred at this time (Maisin, 1968a, b).

There have been several studies of radioprotective formulas containing histamine. The authors of these studies were not by any means governed by a desire to develop formulas for clinical medicine; as a rule, their objective had been to determine some aspects of the mechanism of action of RPA. Nevertheless, some interesting data were obtain that had a direct bearing on the problem of development of radioprotective formulas. In particular, it was established that histamine enhances the protective action not only of sulfur-containing products, but indolyl alkylamines (P. G. Zherebchenko, 1971; T. G. Zaytseva, 1974; Langendorff, 1977; Zherebchenko and Zaitzeva, 1970). Thus, there was a 40-50% increase in survival of mice exposed to minimum absolutely lethal dose of radiation with preventive administration of cystamine combined with histamine, while FUD rose to 2 (as compared to 1.6 for cystamine alone). Ye. N. Goncharenko et al. (1970), P. G. Zherebchenko and T. G. Zaytseva (1970) and T. G. Zaytseva (1974) demonstrated that histamine plays a certain role in formation of both the radioprotective and toxic effect of cystamine, cystaphos and mexamine. Previtt and Masacchia (1975) relate the greater preventive effect of formulas that include histamine to his hypoxic influence on radiosensitive tissues.

Studies of the radioprotective effects of sulfur-containing compounds and indolyl alkylamines used in combination revealed that there was not only an increase in the protective effect, but prolongation thereof. G. M. Ayrapetyan et al. (1969) observed that the high radioprotective efffect (80-85% survival of animals) of a complex consisting of cystaphos (350 mg/kg) and mexamine (60 mg/kg) was manifested for 3 h after hypodermic injection, whereas the effect of the products given separately diminished drastically within 1-1.5 h. Prolongation of the protective

effect was observed after intraperitoneal injection of cystamine combined with mexamine (Vacek et al., 1975), as well as intragastric administration of a mixture of cystaphos, mexamine and sodium nitrite (L. F. Semenov et al., 1972). Evidently, the vasoconstrictive effect of mexamine plays a rather important role in prolonging the protective action, and as a result of this effect there is slower elimination of RPA from tissues and the body as a whole (G. M. Ayrapetyan et al., 1969; V. V. Mordukhovich, 1975).

Analysis of data pertaining to the combined use of RPA shows that AET, cystamine and serotonin constitute the active part of multicomponent mixtures. Glutathione, cysteine or aminazine are added to the formula more for the purpose of lowering toxicity than enhancing their protective effect (Maisin, 1968a, b; Maisin et al., 1968; Maisin and Mattelin, 1967; Vogel et al., 1969; Hasegawa and Yang, 1971, and others). Such four-, five- and six-component mixtures have high radioprotective activity and are tolerated satisfactorily. Their FUD, calculated according to $LD_{50/30}$, reaches significant levels (from 1.8 to 3.0), which is indicative of high radioprotective activity of such formulas in cases of supralethal doses of radiation (Duplan et al., 1976; Maisin et al., 1971; Maisin, 1975).

The mechanism of enhancement of radioprotective action of thiols and indolyl alkylamines when given together is not yet determined. In the opinion of Langendorff, thiols, particularly AET, enhance the pharmacological action of indole compounds due to depression of monoamine oxidase activity, as a result of which better conditions are created for protection of the gastrointestinal tract (Langendorff, 1970; H. Langendorff and M. Langendorff, 1973; Plzak and Rosenkoetter, 1969). It was established that a combination of various RPA elicits more marked depression of DNA synthesis and extension of the cell cycle of stem cells of the small intestine (Maisin and Mathelin, 1967; Maisin and Lambiet-Collier, 1967a, b). At the present time, a certain role is attributed to the adenyl-3,5-adenosine monophosphate system in the mechanism of radioprotective action of the most effective RPA, cystamine, serotonin and AET, and, consequently, of complexes based on them (H. Langendorff and M. Langendorff, 1971). These data are consistent with the findings of McManus and Whitfield (1969), Sutherland (1970) and Mitrnegg (1973), who established that it was possible for cAMP to have an inhibitory effect on DNA synthesis and proliferation of hemopoietic cells. At the same time, such a hypothesis by no means contradicts the conception existing in radiobiology that mixed disulfides play an important role in the protective effect of sulfur-containing RPA.

When developing radioprotective formulas, one must take into consideration the pharmacodynamics of products, their interaction. Thus, the peaks of protective action of sulfur-containing products and indolyl alkylamines do not coincide in time, so that it is desirable to administer them at differet preradiation times, when used in combination. In the case of parenteral administration, it is usually recommended that sulfur-containing products be given 15-30 min before irradiation and indolyl alkylamines 5-10 min before (Ye. A. Dikovenko et al., 1972; Maisin et al., 1971;

Pospisil and Netikova, 1976). The different rates of absorption and elimination of the products may also have an appreciable influence on their radioprotective activity. In particular, when cystamine and mexamine are given simultaneously by mouth, the latter makes absorption difficult, as a result of which the effect of the complex does not exceed appreciably the protection provided by each of the products separately (B. I. Davydov and V. A. Kozlov, 1973).

Since sulfur-containing RPA are still the most acceptable for clinical use (by virtue of their capacity to protect the body when given by mouth, stability when stored, rather long action, etc.), of great interest are studies dealing with the radioprotective effect of various combinations of sulfur-containing RPA. Radioprotective activity was observed with the use of cystamine or cystaphos combined with cysteine (P. G. Zherebchenko et al., 1973), mercaptoethylguanidine with cysteamine (Takagi et al., 1971), cystaphos or AET with aminopropylaminoethyl thiophosphate (P. G. Zherebchenko et al., 1976). A high radioprotective effect of these mixtures was observed when animals were exposed not only to minimum lethal, but supralethal doses of radiation. These results indicate that the maximum protective action (so-called saturation effect) observed with the use of sulfur-containing RPA can be exceeded by a combination of products similar in chemistry. The possibility of mutual attenuation of toxicity is an important justification for the combined use of thiol compounds. In particular, the combined use of aminopropylaminoethyl thiophosphate and cystaphos (P. G. Zherebchenko et al., 1976), AET and mercaptopropylglycine (Santha et al., 1972), AET and 2-mercaptopropionylglycine (Satanyik and Santha, 1976), mercaptoethylguanidine and cysteamine (Takagi et al., 1971), cystaphos and AET (T. N. Pugacheva et al., 1972; T. N. Pugacheva, 1971), AET and cysteine (Santha and Sztanyik, 1972; Sztanyik and Santha, 1976) makes it possible to reduce toxic and certain side-effects induced by these agents when given separately.

Of great interest are data concerning the radioprotective action of sulfur-containing RPA combined with certain biopolymers, hormone preparations, nucleic acids and ATP. B. P. Lukashin and T. K. Dzharak'yan (1973) observed distinct enhancement of protection following the combined administration of cystamine (30 mg/kg) and heparin (250 mg/kg). The FUD of this complex constituted 1.8, according to the survival rate of irradiated mice. These authors relate the enhacing effect to intensification of proliferative processes in lymphoid tissue and pool of colony-forming units of bone marrow (B. P. Lukashin, 1974; B. P. Lukashin and L. I. Nenarokova, 1977), which is apparently due to the stimulating influence of heparin on synthesis of DNA, RNA and proteins (R. I. Salganik et al., 1962; Allfrey and Mirsky, 1955; Zimmerman and Celozzi, 1961; Benes and Rotreklova, 1970).

A high radioprotective effect (93% survival) was obtained in experiments on mice exposed to radiation in a dose of 850 R with the use of ATP combined with AET and serotonin (I. Bayev and D. Benova, 1975; Benova, 1976).

The desire to obtain the maximum radioprotective effect makes it necessary to use a product in a formula in amounts that often correspond to its maximum tolerated dose. Such an approach to development of formulas is attributable to the lack of sufficiently substantiated methods for selecting doses of RPA when used in combinations. We can cite only a few works in which studies and analysis are made of the toxicity of radioprotective mixtures (G. V. Kalistratov et al., 1972; T. N. Pugacheva et al., 1972; P. G. Zherebchenko et al., 1974; T. G. Zaytseva, 1974; Dostal and Mencl, 1971) or pharmacological characteristics thereof are described (Kuna and Vonroublicky, 1969; Kuna and Vodicka, 1973; Kuna, 1975, 1976). Yet toxic signs may be quite marked. Considerable impairment of hemodynamics was observed by Hasegawa and Wang (1971) when animals were given a mixture of AET, cysteamine and serotonin (in doses of 100, 120 and 40 mg/kg, respectively). The animals developed a state of shock and death usually occurred within 20-30 min after administration of the products. Since radiation can intensify the toxicity of some RPA, there is an urgent need to develop formulas including corrective agents. In the last few years, it was shown that drugs can attenuate substantially manifestation of toxicity of RPA with virutally no change in radioprotective activity. The most important results in this direction, which are of definite practical interest, were obtained in the laboratories of P. G. Zherebchenko, P. P. Saksonov, L. A. Tiunov and others. It was established, in particular, that hormones (P. G. Zherebchenko and T. G. Zaytseva, 1967; T. G. Zaytseva, 1974), barbiturates (Yu. Ye. Strel'nikov et al., 1969; P. G. Zherebchenko et al., 1968, 1974; S. M. Smirnova et al., 1975; T. G. Zaytseva, 1974), antihistamines (P. G. Zherebchenko and T. G. Zaytseva, 1970), as well as tranquilizers (Ye. A. Cherepkov and P. G. Zherebchenko, 1972; Ye. M. Cherepkov, 1973), amino acids--cysteine and glutathione (P. G. Zherebchenko et al., 1974, 1976; Maisin et al., 1968)--and certain other pharmacological antagonists (Santha and Sztanik, 1970, 1972) may have a beneficial effect on tolerance of RPA. We can expect a beneficial effect of such drugs when they are used in complex, multicomponent formulas. This is backed up by data pertaining to the possibility of lowering the toxic effects of radioprotective mixtures by including cysteine and glutathione in them (Maisin et al., 1977; Duplan et al., 1976). Attenuation of the toxic effect with the use of low molecular thiols is attributable to their capacity, first of all, to diminish accumulation of sulfur-containing RPA in the brain (P. G. Zherebchenko et al., 1974). A beneficial effect was also demonstrated with the use of aminazine in a complex with AET, cysteamine and serotonin (Hasegawa and Wang, 1971).

In summary, it should be stated that, at the present time, it is only by developing radioprotective formulas that a better chemical protective effect can be obtained with exposure to ionizing radiation. In the last few years, most authors have proceeded along the route of development of multicomponent formulas. Such formulas are based on sulfur-containing RPA, with inclusion of radioprotective products with a different mechanism of action and pharmacological agents that attenuate the side-effects and toxic effects of RPA. Much attention is being devoted to the study of the

mechanism of action and reciprocal influence of different components in the formulas, as well as the effects of enhancement, summation, etc. All this makes it possible to select substances contained in the formulas with greater justification and purposefulness, and to determine the dosage of different components in radioprotective formulas.

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THE ROLE OF STRESS IN THE MECHANISM OF LONG-TERM ADAPTATION, AND PREVENTION OF STRESS-RELATED INJURIES

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[Article by P. K. Meyerson, USSR Academy of Medical Sciences Institute of General Pathology and Pathological Physiology]

[Text] Individual or phenotypic adaptation can be defined as a process developing in the course of individual life, as a result of which the body acquires formerly absent resistance to a certain environmental factor, and thus obtains the possibility for living in conditions formerly not compatible with life, and to engage in formerly impossible tasks.

Obviously the capability for "living in conditions formerly not compatible with life" may correspond in this definition to complete adaptation which, in the presence of cold or a lack of oxygen, insures performance of a broad range of behavioral reactions and survival of the species and, on the other hand, to highly incomplete adaptation, which makes it possible to preserve only life itself for a more or less long period of time. In similar fashion, the possibility for "engaging in formerly impossible tasks" embraces both the most primitive and the most complex tasks--from the ability to avoid an encounter with a predator by means of the passive defensive reflex of freezing one's position, to the ability to journey into space and consciously control the body's vital activities. In my opinion this intentionally broad definition corresponds to the real significance of adaptation, which is an inseparable attribute of all life, and which is characterized by the same diversity as life itself. However, in this case we concentrate our attention on the results of adaptation, on "raising resistance," on "problem solving," and not on the essence of the process, which proceeds in the body under the influence of environmental factors and leads to realization of adaptive achievements. In my point of view this reflects the real state of affairs in the science of adaptation--adaptology, one in which the remarkable diversity of the outward manifestations of adaptation far from always helps us to reveal the fundamental mechanism of this phenomenon, common to the most diverse cases. As a result the question as to what sort of concrete mechanism, and what chain of events causes an unadapted organism to transform into an adapted one, is presently the main and, in many respects, unresolved problem of phenotypic adaptation. It is to this problem that the present article is devoted.

The Mechanism of Phenotypic Adaptation and the Role Played by the Stress Syndrome Within It

We can answer the question as to the mechanism of adaptation in general form by saying that all variants of adaptation are based on increasing the capacity of systems participating in the body's reaction to a given factor. However, this notion reflects only the external side of the phenomenon. To reveal the mechanism of interest to us, we must answer the question as to why the capacity of systems responsible for adaptation grows.

Research conducted in the last decade by mine and other laboratories showed that intense and prolonged action by environmental factors produces a fundamental phenomenon that is the keystone of adaptation--synthesis of nucleic acids and proteins is activated in the cells of systems and organs carrying the main burden. In the cells, this activation leads to structural alterations which significantly raise the capacity of reacting systems and which makes up the basis of adaptation. The process develops in such a way that intensification of cell function produces a deficiency of energy-rich phosphorus compounds in the cells. Operating through intracellular regulatory mechanisms, this chain activates the genetic apparatus of the cells--it increases the rate of RNA transcription on structural genes contained in DNA of the cell nuclei. The resulting enlargement of the quantity of polysomes becomes the cause of an increase in the rate of protein biosynthesis. This is why the entire mechanism is referred to as the "mutual relationship between function and the genetic apparatus of the cell" (8, 11).

For practical purposes any long-term adaptive reaction by the body demonstrates the significance of this relationship. Thus as the body adapts to physical loads, synthesis of nucleic acids and proteins regularly undergoes pronounced activation in motor center neurons, in adrenal glands, and in skeletal muscle and heart cells (2, 29, 31).

Figure 1 demonstrates such activation of nucleic acid and protein synthesis in heart muscle in response to repeated physical loads. This activation is sharply pronounced in cell nuclei, in mitochondria, and in membranes of the microsomal fraction. As a result of activation of biosynthesis in heart muscle, the mass and capacity of structures responsible for control, for ion transport, and for energy supply selectively increase. Thus it has been demonstrated that in the course of adaptation to physical loads, moderate hypertrophy of the heart combines with an increase in activity of the adenyl cyclase system (53) and a rise in the number of adrenergic fibers per unit mass of the myocardium (42). As a result the adrenoreactivity of the heart--the possibility for promptly mobilizing its function--increases.

We simultaneously observed an increase in the quantity of H-bands, which are the bearers of ATP-ase activity in the head end of myosin (31); ATP-ase activity rises, and as a result the rate and amplitude of heart muscle contractions increase (20).

The capacity of the calcium pump of the sarcoplasmic reticulum subsequently increases, and as a consequence the rate and depth of the heart's diastolic relaxation rise (13). In parallel with these changes, the quantity of coronary capillaries in the myocardium increases (46), the concentration of myoglobin rises (27), and the

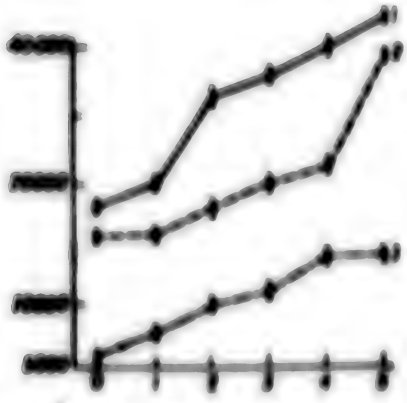


Figure 1. Inclusion of [^{3}H] Into the RNA of Subcellular Factions of the Left Ventricle of Rats Learning to Swim: 1--in mitochondria, 2--ribosomes, 3--in nuclei; abscissa--training time (days); ordinate--RNA specific activity (from Caldarera et al.)

activity of enzymes responsible for transport of substrates to mitochondria increases (52); the mass of the mitochondria themselves increases. This rise in capacity of the energy-supply system naturally produces an increase in the heart's resistance to tiring and hypoxemia (48).

An important point is that activation of protein synthesis and selective enlargement of the capacity of structures responsible for control, for ion transport, and for energy supply are not unique attributes of the heart: They occur naturally in all organs responsible for adaptation. During adaptation, these organs make up a single functional system taking form on the basis of laws thoroughly examined in the past by A. A. Ukhtomskiy (28), and later by P. K. Anokhin (1). In and of itself, however, arisal of such a system is not enough for complete long-term adaptation. Adaptation is achieved after selective enlargement of the mass and capacity of structures responsible for control, ion transport, and energy supply develops, as examined above on the example of the heart, in all organs forming the functional system, as a result of the activation of nucleic acid and protein synthesis. In their sum total, these structural alterations produce a systemic structural imprint which broadens the functional limits of the system responsible for adaptation, and thus becomes the basis for stable long-term adaptation (14, 15).

Thus in adaptation to physical loads, this systemic structural imprint manifests itself at the level of nervous regulation as hypertrophy of neurons in the motor centers, and as an increase of the activity of respiratory enzymes within them (39); it manifests itself at the level of endocrine regulation as hypertrophy of the adrenal cortex and medulla (50); it manifests itself at the level of actuating organs as hypertrophy of skeletal muscles and very significant increase in the number of mitochondria they contain (37). This last shift promotes an increase in the organism's capacity for aerobic respiration, and its endurance. Thus the far-reaching structural imprint broadens the limits of the body's ability to function, and thus creates the basis of dependable long-term adaptation.

That the body's adaptation to various environmental factors produces systemic structural imprints of varying architecture is significant.

As an example during adaptation to high-altitude hypoxia, nucleic acid and protein synthesis undergoes activation and the mass of certain cellular structures in the hemopoietic apparatus, the lungs, the heart, and the brain increases (12). This results in formation of a far-reaching structural imprint promoting an increase in the functional capacity of many organs.

Figure 2. Influence of Adaptation to High-Altitude Hypoxia on RNA Concentration (Broken Curve) and Protein Synthesis (Continuous Curve) in the Lungs (*A*), the Heart (*B*), and the Brain (*C*). Abscissa--time of hypoxia (days); ordinate--RNA concentration and protein synthesis intensity (percent of initial level)

The curves in Figure 2 demonstrate activation of nucleic acid and protein synthesis in the brain, lungs, and heart during adaptation to periodic hypoxia in a pressure chamber. The systemic structural imprint, developing as a result of this adaptation in circulatory and respiratory organs, is not identical to that observed during adaptation to physical loads, just examined above in detail, but it is similar to it. One difference is that with adaptation to hypoxia, the supraoptic nucleus of the hypothalamus (6) and the glomerular zone of the adrenal glands (45) undergo partial atrophy. This component of the systemic structural imprint, absent from adaptation to physical loads, promotes an increase in the body's resistance to excess sodium and water, and a decrease in resistance to their deficiency. Another difference is that structural changes typical of adaptation to physical loads are absent from the locomotor apparatus. In other words the architecture of systemic structural imprints typical of these two variants of adaptation differs.

A systemic structural imprint of completely unique architecture also forms in the course of the body's most sophisticated adaptive reactions at the level of the brain. In fact, we know today that the mutual relationship between function and the genetic apparatus is realized with extremely high intensity and speed in cerebral neurons. Arousal of certain cortical neurons at the time of development of a temporary association is naturally accompanied by activation of RNA and protein synthesis in these neurons (39). Proteins formed as a result of this activation pass from the body of the neuron into its branches and predetermine reorganization of synaptic interneuron associations. As a result a certain system of structurally associated neurons forms.

This systemic structural imprint is the basis of memory consolidation, and the basis of fixation of a temporary association (7, 9).

Thus we arrive at the premise that a systemic structural imprint is the real foundation of all long-term adaptive reactions acquired in the course of life.

To understand the general mechanism of adaptation, it is important to realize that in the whole body, the systemic structural imprint making up the basis of adaptation forms with the predominate participation of neuroendocrine mechanisms, and mainly those of the stress syndrome, which H. Selye described, with amazing accuracy, as the "general adaptation syndrome" (25).

As we know, the stress syndrome arises in response to the initial action of any sufficiently strong environmental factor upon the body, and it has its roots in the fact that arousal of higher autonomic centers causes activation of the adrenergic and hypophysoadrenal systems; as a result the concentration of catecholamines and glucocorticoids rises in the blood.

Catecholamines mobilize the liver glycogen reserve and activate lipolysis in fatty tissue. Given simultaneous hyperventilation and enlargement of the heart's minute volume, this causes an increase in the inflow of oxygen, glucose, and fatty acids into tissues.

In many tissues glucocorticoids inhibit synthesis of protein and activate its breakdown. As a result the concentration of amino acids rises in the blood, and transformation of amino acids into glucose--transformation of the body's structural reserve into an energy reserve--undergoes activation (5).

The stress syndrome is commonly viewed on the basis of these well-known factors as a generalized reaction of mobilization of the body's energy and structural resources. However, a more-careful analysis would show that this definition does not fully embrace the essence of the phenomenon, since mobilization of energy and structural resources combines, in the presence of stress, with their nonuniform distribution. For example it has been demonstrated that readiness to fight or to do physical work is characterized not only by general mobilization of respiration and circulation, and not only by hyperglycemia and hyperlipemia, but also by significant contraction of vessels supplying abdominal organs and inactive muscles, coupled with simultaneous dilation of vessels supplying the working muscles (30). This means that excess oxygen, glucose, and fatty acids arising in response to the action of catecholamines are selectively directed to a particular address, mainly to the system responsible for the amplified function.

This nonuniformity in distribution of resources liberated at the time of stress reveals itself even more distinctly in application to the action of glucocorticoids. For example the concentration of glucocorticoids is known to rise dramatically in the blood in response to the first significant physical load. Concurrently we witness a negative nitrogen balance, loss in weight and atrophy of the thymus, and eosinopenia (3). It was found that this classical catabolic effect of glucocorticoids is regularly associated with activated synthesis of nucleic acids and proteins in skeletal muscles and in the heart (29). Such activation involves the use of the excess amino acids and nucleotides available in the blood--skeletal muscles and the heart undergo hypertrophy on the background of a general decrease in body weight.

Surgical creation of significant stenosis of the mouth of the aorta in animals is accompanied, in similar fashion, by development of the stress syndrome together with pronounced atrophy of the thymus, which loses almost all of its thymocytes. It is on this background that nucleic acid and protein synthesis undergo significant activation in heart muscle; the heart experiences swift hypertrophy (10). There are many similar factors. Taken all together, they lead to the impression that the stress syndrome involves not just simple mobilization of the body's energy and structural resources, but also radical transformation of the resources--their directed transfer from inactive systems into systems responsible for adaptive hyperfunction--that is, to systems in which an adaptive structural imprint is formed on the basis of the mutual relationship existing between function and the genetic apparatus. Thus we can say that stress is the means by which the body's structural and energy resources are concentrated in systems responsible for adaptation.

Another no less important contribution of the stress syndrome to adaptation is that catecholamines, glucocorticoids and, possibly, other hormones, the secretion of which is activated during stress, have a direct influence upon the function and metabolism of systems responsible for adaptation--that is, on the function and metabolism of systems in which the structural imprint just examined forms. As an example it was established in recent years that ACTH liberated during stress not only activates secretion of glucocorticoids by the adrenal cortex but also has a direct activating influence upon synthesis of nucleic acids and proteins in the brain--that is, it activates the process of consolidation of a temporary association (47), or, in other words, formation of a systemic structural imprint. Thus it may be suggested that the role of the generalized stress syndrome, arising nonspecifically in response to the action of various factors, is that it potentiates formation of the specific component of adaptation--namely, formation of a structural imprint, and enlargement of the capacity of systems directly responsible for the body's adaptive reaction to the given, concrete environmental factor. The known fact that in response to repeated action of intense stimuli upon the body the stress syndrome gradually undergoes extinction as the systemic structural imprint at the basis of adaptation forms is in keeping with this interpretation of the role of the stress syndrome in development of long-term adaptation. Thus as physical loads are repeated, the increases in the blood corticosterone concentration becomes increasingly less pronounced (3), and concurrently the capacity of mitochondrial systems in skeletal muscles and the maximum duration of a load that man and animals could impose increase (35). In entirely similar fashion, when an individual is first presented a new important problem requiring swift solution, we observe many errors, and a sufficiently pronounced stress syndrome develops. As this situation is repeated and as the systemic structural imprint making up the basis of newly formed associations and habits forms in the brain, the errors gradually disappear and the stress syndrome begins to be superfluous, thus undergoing extinction (24).

These interpretations of the mechanism of phenotypic adaptation are summarized in the diagram in Figure 3.

The diagram shows that disturbance of homeostasis by an environmental factor, or a signal that such disturbances are possible in the future, activates, through higher regulatory mechanisms, the systems responsible for adaptation. As a result two phenomena arise: first, mobilization of the functional system specifically responsible for adaptation to the given factor (shown in the upper part of the figure) and, second, the nonspecific stress syndrome (shown below).

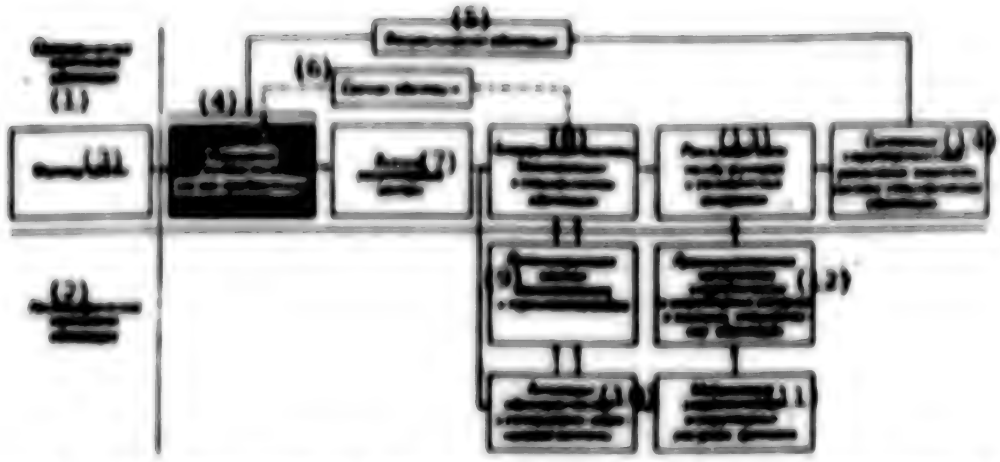


Figure 3. The Mechanism of Phenotypic Adaptation: Explanation in text

Key:

1. Specific adaptation component
2. Nonspecific adaptation component
3. Environmental factor
4. Disturbed homeostasis or its precursors
5. Phenotypic adaptation
6. Immediate adaptation
7. Higher regulatory centers
8. Hyperfunction of systems dominating in specific adaptation
9. Potentiating influence of catecholamines and corticosteroids
10. Activation of adrenergic and hypophyseoadrenal systems
11. Mobilization of the body's energy and structural resources
12. Predominant entry of energy and structural resources into the specific adaptation system
13. Realization of relationship between function and the genetic apparatus
14. Systemic structural imprint--enlargement of the capacity of specific adaptation systems

Subsequently the specific adaptation system promotes hyperfunction and it dominates the body's vital activities. On the basis of the relationship between function and the genetic apparatus, and in the presence of the potentiating influence of the stress syndrome, a structural imprint forms within cells of this system; owing to the previously examined selective enlargement of key cell structures, this imprint significantly raises the system's capacity. Dependable, long-term adaptation develops, eliminating the initial disturbances in homeostasis and making the stress syndrome superfluous.

After the given environmental factor's action upon the body ceases, the function of the system responsible for adaptation declines dramatically, and owing to the relationship between the function and the genetic apparatus, synthesis of nucleic acids and proteins in the cells forming the system decreases and the systemic structural imprint disappears--deadaptation occurs. In the course of its individual life, the organism encounters the entire set of factors of the surrounding world, and as a result we observe formation, on the basis of the mechanism just examined,

of not just one structural imprint but a complex set of systemic structural imprints that alternate with one another and deeply alter the countenance of the organism--they form its phenotype over certain more or less lengthy intervals of time.

It is significant that the systemic structural imprint, which plays the main role in specific adaptation namely to the given concrete environmental factor, forms with the necessary participation of the nonspecific stress syndrome, which normally arises in the presence of any significant alteration in the environment. In this case the stress syndrome on one hand potentiates formation of a new systemic structural imprint and development of adaptation, while on the other hand it promotes, through its catabolic action, "erasure" of old systemic imprints that have lost their biological significance. Thus this syndrome is a necessary element of the integral mechanism of adaptation-deadaptation of the body in relation to a changing habitat; it plays an important role in reprogramming the adapative possibilities of the body for solution of new problems posed by the environment.

This interpretation of individual adaptation as a dynamic process lasting through one's entire lifetime provides the grounds for distinguishing the principal stages of this process, and the adaptation diseases that are the most probable in each of these stages.

The first stage of immediate adaptation is typified by mobilization of pre-existing adaptation mechanisms--hyperfunction--or initial formation of a functional system responsible for adaptation. Despite its imperfections, this structurally unsupported hyperfunction provides the organism a possibility for "holding on" until development of long-term adaptation. In behavioral terms, this stage consists of wasteful, and only occasionally successful orientation reactions; in terms of adaptation to a physical load, this stage can be described as one of work raised to the limit, together with maximum minute circulatory volume and respiration, a high, close-to-critical blood lactate concentration, and so on. There are three elements lying at the basis of this initial stage: hyperfunction of the system specifically responsible for adaptation to the given factor, the stress syndrome, and disturbance of functions resulting from the homeostatic changes occurring.

Obviously when some element of a system called upon to participate in a reaction to a new environmental factor suffers a congenital or acquired deficiency, immediate adaptation may be so imperfect that the organism falls ill or avoids solution of the problem dictated by the environment; diseases associated with adaptation unfulfilled may correspond to these situations.

The second stage, transition from immediate to long-term adaptation, is typified by activated synthesis of nucleic acids and proteins in cells of the systems specifically responsible for adaptation--enlargement of the capacity of this dominating system and gradual abatement of the stress syndrome. Stable adaptation develops subsequently in most cases.

However, the transitory stage may drag on in so-called "irresolvable situations," in which the factor acting upon the organism is excessive in its strength, or where the situation arising in the environment is excessively complex, thus making the required adaptive reaction unrealizable. In such situations an effective functional system and a systemic structural imprint do not form. As a result the initial disturbances in homeostasis persist, and the stress syndrome stimulated by them

attains excessive intensity and duration. It is precisely in this situation that the syndrome may transform from an element of adaptation into an element of pathogenesis, and that numerous stress-related illnesses may arise--from gastric ulcer and severe heart damage (16) to growth of blastocytomas, the role of the stress syndrome in which has been confirmed by recent experimental (49) and epidemiological research (38).

The third stage of formed long-term adaptation is characterized by presence of systemic structural imprint, absence of the stress syndrome, and improved adaptation to the given factor or situation. When adaptation of this sort is excessively acute and narrow, dominance of a particular system in accordance with the basic principle of dominants may lead to one-sided development of the organism. Thus reduction the structural reserve of the liver and kidneys in response to adaptation of animals to physical loads (32) or development of an immunodeficient state in response to adaptation to significant hypoxia have been demonstrated. Such "disarmament" of particular body systems may become the cause of diseases of one-sided development.

The fourth stage, exhaustion, is not mandatory. It develops only in response to excessive, stressful adaptation, and it is typified by the fact that a high load upon systems dominating in adaptation leads to excessive hypertrophy of their cells, and later to inhibition of RNA and protein synthesis, disturbance of structure renewal, and wear-and-tear coupled with development of organic and systemic sclerosis. This situation had been examined in detail earlier (9).

It is important to consider here that the possibility of adaptation's transition into disease--the relative suitability of adaptation--does not provide the grounds for a pessimistic evaluation of this process, since the body does manage to adapt successfully to most real situations in the surrounding environment. That the body's evolutionarily determined reactions are so perfect is a consequence of, first, the fact that the body possesses a system of behavioral reactions permitting it to avoid excessively long contact with physical and chemical environmental factors creating a direct load upon functional systems, and thus avoid excessively stressful and lengthy adaptation. Second, severe, long-lasting stress accompanying "irresolvable situations" undergoes extinction with time, since the body has specialized systems that limit stress and prevent stress-related injuries (16). Third and finally, even prolonged stressful adaptation to a continuously operating environmental factor far from always leads to disease, since the duration of the stage of stable adaptation is in many cases close to the life span typical of the species.

Obviously, active prevention of adaptation diseases by man may be most effective if we capitalize on the natural physiological mechanisms through which the body itself resolves this problem. In addition to behavioral mechanisms promoting timely escape from extreme situations and harmonious development, systems that limit or weaken the stress syndrome and thus prevent stress-related injuries in times where extreme situations cannot be avoided or must not be avoided are of great interest in this regard. Prevention based on imitation of such systems entails introducing active metabolites produced by antistress systems into the body prior to experiencing the stressful situation, or during it, thus preventing stress-related injuries.

Prevention of Stress-Related Injuries

The notion that stress plays a role in pathology is so popular that it often detracts researchers from its fundamental, evolutionarily determined role as an element of adaptation, and keeps them from concentrating their attention on the highly important circumstance that most people and animals, when placed in so-called irresolvable situations, do not perish, instead acquiring a certain degree of resistance to these stressful situations, and not perishing.

Such stressful situations, taking the form of prolonged periods of starvation, cold, natural disasters, and interspecific and intraspecific conflicts are always broadly represented in the natural habitat, to which animals have adapted themselves successfully. The qualitatively more-complex socially determined stressful situations of the habitat of *Homo sapiens* are represented no less broadly. In fact, in just the recent, relatively short segment of its history, mankind has passed through periods of slavery, serfdom, and world wars, but it has hardly undergone degeneration, thus demonstrating the high effectiveness of adaptation to so-called irresolvable stressful situations.

This means that temporary transformation of the stress syndrome from an element of adaptation to one of pathogenesis is not the end of all life, but only one of its intermediate phases. But such transformation alone is not the entire story--most animals and people do not die from lengthy, recurring exposure to stressful situations, and consequently the organism must possess mechanisms insuring adaptation to stress itself.

It has been experimentally demonstrated that with prolonged and, especially, repeated action of severe stress factors such as immobilization or pain, the degree to which the adrenergic and hypophyseoadrenal systems are activated drops more and more each time (40, 44). Thus the first injection of formalin into skin of the back causes rats to increase the concentration of corticosterone in their blood by a factor of 4.5, while the 22d through 27th injections have no influence upon the concentration of the hormone at all. Such cessation of the first reaction does not have anything to do with exhaustion of the adrenal glands--injection of ACTH into animals adapted to pain produces a higher increase in blood corticosterone concentration than in control animals. These data suggest the thought that one of the factors responsible for adaptation to unavoidable stressful situations in the environment is activation of regulatory mechanisms which inhibit, in response to pain and other stimuli, production of releasing factors, ACTH, and consequently corticosterone and catecholamines. Inhibitory mediators--GABA [gamma-aminobutyric acid], glycine, dopamine, serotonine, and encephalines--are synthesized and discharged by systems of inhibitory neurons in the brain. It may be presumed that these inhibitory systems of the body are precisely what limit the stress syndrome and play a certain role in adaptation of the body to irresovable, at first glance, stressful situations.

In similar fashion, regulatory systems represented by the adenine nucleotides, prostaglandins, and antioxidant systems operate on the periphery; playing the role of modulators, they limit the effect of catecholamines, thus averting stress-related injuries.

Studying adaptation to stressful situations, I experimentally demonstrated that at least two of the mentioned systems--the GABA-ergic system of the brain (18) and the

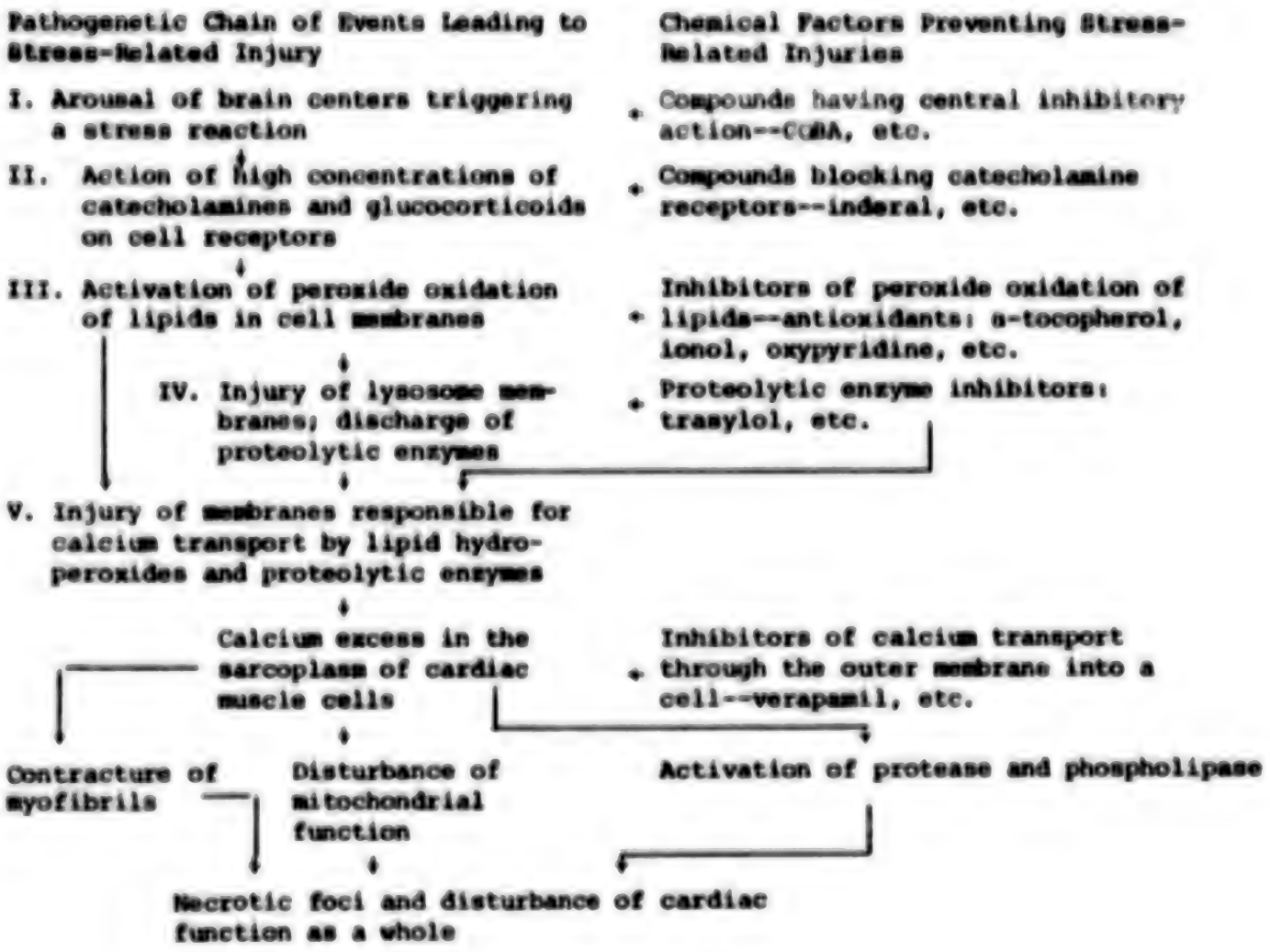
tissue antioxidant system (19)--are in fact activated in the presence of the most diverse stressful situations, and that the metabolites of these systems may prevent stress-related injuries to the body, and mainly stress-related gastric ulcers and disturbances in the structure and function of the heart (16). This result was made possible owing to development, in recent years, of the hypothesis that stress-related injury to the heart and other organs follows a pathogenetic chain of events: Blockage of certain links of this chain by antistress metabolites and other chemical factors can avert stress-related injuries. The pathogenetic chain of events leading to stress-related injury, diagramed below, summarizes data obtained in research on the metabolism, functions, and structure of the heart of animals surviving severe emotional and painful stress,* reproduced in the form of so-called anxiety neurosis by Desiderato's well-known technique (34). The main feature of the stressful situation created here is that for several hours the animal anticipates a painful electric shock, and it does in fact receive such shocks after random intervals of time.

The diagram shows that in the presence of such influences, arousal of higher autonomic centers responsible for a stress reaction leads to multiple enlargement of the concentration of catecholamines in blood (the first link).
Catecholamine action upon adrenoreceptors (the second link) located in the sarcolemma of the myocardium causes, in addition to the known consequences of activation of the adenyl cyclase system, development of a highly important phenomenon--activation of peroxide oxidation of lipids (POL) which, as my experiments showed, is the third and keystone link of the pathogenesis of stress-related injury. Subsequently, under the influence of POL products--lipid hydroperoxides--lysosomes undergo lysis to release, into the sarcoplasm and blood, proteolytic enzymes capable of damaging cell structures. Owing to the simultaneous action of lipid hydroperoxides and proteolytic enzymes, injuries occur in membranes of the sarcoplasmic reticulum responsible for transport of Ca^{2+}, its timely removal from the sarcoplasm, and relaxation of myofibrils. As a result the next, fifth link of the pathogenic chain of events is realized--the concentration of Ca^{2+} in the sarcoplasm of heart muscle cells rises. Excess Ca^{2+} produces a complex of changes termed the calcium triad (23), consisting of contracture of myofibrils, injury of mitochondria leading to disturbance of the link between oxidation and phosphorylation, and activation of phospholipase and protease. Development of this triad causes irreversible contracture and necrobiosis of individual groups of cells, and pronourced disturbances in the contractile function of the heart as a whole (see the sixth link of the pathogenic chain in the diagram).

It is extremely significant that these focal disturbances of heart structure and total disturbances of heart function were clearly pronounced after the stressful situation passed--they were not just reactions to a stress factor, but relatively stable consequences of injury occurring during the time of stress. This fact, taken together with clinical data on the role of emotional stress in the etiology

* This diagram is based on the results of experiments performed in the cardiac pathophysiology laboratory of the USSR Academy of Sciences Institute of General Pathology and Pathological Physiology, in the laboratory of biological membrane physical chemistry of the Moscow State University biology department, in the Central Scientific Research Laboratory of the Irkutsk Medical Institute, and in the biochemistry department of the Chelyabinsk Medical Institute.

Stress-Related Injury of the Heart, and Its Chemical Prevention



of circulatory diseases, provides the grounds for suggesting that these relatively persistent disturbances in metabolism and function, which persist after the stress itself disappears and accumulate from one stressful experience to the next, are precisely what may play a role in gradual development of those forms of so-called primary noncoronarogenic cardiosclerosis and chronic cardiac insufficiency which often arise in people who had not formerly suffered circulatory diseases. It is at the same time highly probable that the described complexes of stress-related disturbances may superimpose themselves over changes arising in the heart as a result of basic circulatory diseases, and thus potentiate the breakdown of compensation and development of cardiac insufficiency in the presence of cardiac ischemia, heart failure, and hypertension.

Thus stress-related injury, the pathogenesis of which is reflected approximately by the diagram above, plays an important role in the arisal of the basic forms of cardiac insufficiency. There is a great deal of evidence that this chain of phenomena, the existence of which was proven by me in application to cardiac striated

muscle in the presence of stress, also applies to the smooth muscle of blood vessels.

Contractural spasm of this musculature leads to ischemic focal injury of the most diverse organs, typical of stress. This development of events has now been proven in application to gastric ulcers, which are the result of ischemic necroses of the mucous membrane elicited by adrenergic spasm of vessels and subsequent digestion of ischemic portions of the mucous membrane (36, 41).

In full correspondence with this, the chemical factors on the right side of the diagram, which I used to prevent stress-related injuries following the principle of simulating the body's natural antistress system, prevented not only heart injury but also stress-related gastric ulcers.

Thus the diagram approximately characterizes the basic links of the pathogenesis of stress-related injuries to the body, and the basic possibilities for preventing such injuries. As shown in the diagram, arousal of higher autonomic centers triggering the stress syndrome was suppressed with the use of a metabolite of the brain's inhibitory GABA-ergic system--gamma-oxybutyric acid (GOBA). Preliminary research showed that in the presence of emotionally painful stress (18) and in the presence of other stressful influences of the highest diversity (21), biosynthesis of this system's main inhibitory mediator--gamma-aminobutyric acid (GABA)--is activated in the appropriate brain neurons. The process occurring during stress is such that a significant proportion of the GABA is transformed into GOBA through metabolic reactions of which we are aware of now (44). Formed in the brain, this metabolite has strong independent inhibitory action; in large doses it normally elicits sleep in animals and people (43). It appeared probable that under natural conditions, GOBA is precisely what limits the duration and intensity of the stress syndrome, and thus prevents stress-related injuries. Small GOBA doses (100 mg/kg) that do not have a noticeable influence on animal behavior in the presence of emotionally painful stress, were injected prior to stress exposure on the basis of this hypothesis. It was found that GOBA does in fact inhibit arousal of the adrenergic and hypophysecadrenal systems, and that it completely prevents, first, all of the described disturbances in cardiac metabolism, structure, and function, second, stress-related gastric ulcers and, third, fermentemia, which regularly occurs in animals suffering stress, and which is a good integral indicator of stress-related injury to the body (16).

Blockage of the second link of the pathogenic chain, namely the effect of high concentrations of catecholamines upon adrenoreceptors, was achieved with inderal, which prevented stress-related injury to the heart and, to a significantly lower extent, stress-related gastric ulcers.

To block the third link of the pathogenic chain--POL activation, I once again returned to the natural antistress systems of the body. In normal conditions the level of POL and the ability to form hydroperoxides capable of destroying cell membranes are limited by the body's antioxidant systems, namely the enzymes peroxydismutase, glutathione peroxidase, catalase, and antioxidants, among which vitamin E--a-tocopherol--occupies the most important place. In the presence of stress, POL activation apparently occurs as a result of insufficient capacity of natural antioxidant systems. The antioxidant a-tocopherol (17) and a more-powerful synthetic antioxidant--ionol (dibunol) (19) were used for the first time on the basis of these

considerations in order to prevent stress-related POL activation. Accumulation of hydroperoxides was in fact averted, and the complex of stress-related injuries to the heart and stomach, described above, did not come about.

The fourth link of the pathogenic chain of events in stress-related injury--the destructive action of proteolytic enzymes contained in lysosomes--can in principle be blocked by inhibitors of these enzymes, trasylol in particular. However, the actual preventive effect obtained in this way turned out to be less pronounced than with the use of GOBA, antioxidants, or inderal. Finally, the fifth of the pathogenic links in the suggested diagram--arisal of excess Ca^{2+} in cells--may be blocked by a Ca^{2+} transport inhibitor well known in cardiology--verapamil (isoptin), which binds with the sarcolemma of muscle cells and prevents entry of Ca^{2+} into them. In my experiments, verapamil prevented stress-related injury in the same way that they prevented injuries elicited by administration of large doses of catecholamines in the works of other authors (51).

All of this creates a certain amount of promise for preventing stress-related injuries, but at the same time this approach cannot be extrapolated to the clinic mechanically. The reason for this is that, first, some of the antistress factors employed, for example GABA or ionol, may, if given at imprudent doses, strongly suppress the stress syndrome itself, which is a necessary element of adaptation, and that they may have an influence on behavior disadvantageous to the organism in the given environmental conditions. Second, prolonged administration of chemical antistress factors may suppress the activity of the body's own antistress systems. Therefore in addition to chemical prevention of stress-related injuries, prevention of such injuries by exercising the body's natural antistress systems and raising their capacity acquires important significance. Such a result has been achieved in adaptation of the body to the periodic action of hypoxia in a pressure chamber. It has been demonstrated that adaptation of this sort completely prevents POL activation in cardiac muscle, usually arising under the influence of emotionally painful stress (22), as well as development of the entire complex of stress-related injuries of cardiac muscle described above (19). Research on the mechanism through which adaptation to hypoxia prevents stress-related injuries in similar fashion as do antioxidants showed that such adaptation normally leads to an increase in the capacity of enzymatic antioxidant systems--peroxydismutase, glutathione peroxidase, and catalase (4). Concurrently with adaptation, we observe a decrease in the concentration of unsaturated fatty acids, the principal substrate of POL, in the heart. There are grounds for suggesting that stress-related injuries may be prevented by adaptation not only to hypoxia but also to other environmental factors.

It can be concluded from the above that the combination of adaptive and chemical prevention, based on imitation of natural antistress systems of the body, creates real promise for preventing stress-related injuries in man.

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PSYCHOPHYSIOLOGICAL MECHANISM OF HUMAN ERRONEOUS REACTIONS UNDER CONDITIONS OF THE INTERACTION OF VISUAL STIMULI

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[Text] The study of erroneous reactions, which occur in any form of human activity, their nature and mechanisms, have both theoretical and applied significance: psychological and psychophysiological analysis of erroneous reactions provides important insights into the mechanisms of voluntary motor activity, how information is transmitted, the individual characteristics of reprocessing sensory input and others such as the mechanisms of an appropriate performance of an activity (11), (12), (15), (18). In addition, the process by which erroneous reactions appear involves the organization of different forms of human practical activity during which the number of erroneous reactions must be considered.

Erroneous reactions usually occur during laboratory experiments. Analysis of erroneous reactions provides a way to classify them into errors of a situational character and natural errors; those induced by actions governed by a constant factor (or factors) which occur in given experimental conditions and which determine a significant number of erroneous reactions. The appearance of factors which lead to the occurrence of a series of erroneous reactions of one or another form is of interest.

Erroneous reactions which adhere to an established pattern are a response to separate stimuli and in situations of interaction of two or more sensory motor reactions. Analysis of data in the literature suggests a division of certain factors which determine the regular pattern of a number of erroneous activities of test subjects in situations of reaction to different stimu-

li, delivered at adequately large interstimuli intervals. These stimuli are characterised by the presence of different types of obstacles: inadequate illumination and increased levels of noise, poor discrimination and weak intensity of the stimuli, use of insufficiently distinct stimuli. In addition, key to the appearance of erroneous reactions is the nature of the responsive activity which potentially leads to a large or small probability of error (15); the specific type of influence which prescribes the reaction either in terms of speed or infallibility (17); the process of transforming sensory flow by the sensing organs (6), (7), general and individual typological character of experience; memory and thought and others.

When motor reactions interact as a consequence of the specific character of presentation of visual signals, one of the main factors which leads to the appearance of erroneous reactions is the interaction of inhibitory and activating processes needed to perform the voluntary motor act (2), (9), (14), (19). The well known methodology of A. Ye. Khil'chenko derived in his study on the mobility of basic neurologic processes in man (14), as well as its main variant worked out by M. N. Borisova (3) and incorporated in other studies concerns the appearance of erroneous reactions (1), (4). This method is based on the response to presentation of specific stimuli (visual and auditory). The subject must perform positive reactions with one or another hand and when presented with another group of stimuli must refrain from reacting. Conclusions about the inaction of the inhibitory process are based on when following an inhibitory process for a positive stimuli, the subject responds by an inhibitory reaction. The relative inaction of the stimulation process is judged if after a number of positive stimuli the subject responds to inhibitory stimuli with a positive reaction. The measured rate of responsiveness of neurological processes of the subject is determined by the length of the shortest exposure to the stimuli (according to the method of A. Ye. Khil'chenko) or the dimension of the smallest (critical) interval between stimuli (in the variant of M.N. Borisovna), in which the subject makes no more than 5 percent of errors in the course of 2-3 minutes. This quantity of errors serves as the measure for the initial background level of accuracy of reaction (with the shortest exposition or the smallest interval, the percent of mistakes acutely increases). It is evident that erroneous reactions in this situation occur as a secondary reaction in a situation of sensory motor interaction. However, in studies of this nature, the psychophysiological basis to determine the given quantity of erroneous reactions as a valid way to explain the mechanism of interaction which leads to their appearance, is absent. Moreover, the study of the nature of erroneous reactions has important theoretical and practical significance.

In this article, we will examine the psychophysiological mechanism for the appearance of erroneous reactions which arise in situations of sensory motor interaction.

Method of Investigation

We used the variant method of N.I. Chuprikova (16) and techniques described by us previously (8), (9), (10). The subject was seated in front of a panel of signal lights which formed 4 verticle and 4 horizontal intersecting rows. After a 2 second exposure to a given signal (sound), the subject was shown two consecutive visual signals (of a 100 ms duration), divided into two intervals of 1.7; 2; 3; 5; 6; 8; 10; 14 seconds. During one experiment, the signals were displayed constantly. The signals came from one or another pair of lights. The task required of the subject included pressing as quickly as possible his right hand on the key positioned to the right of the lamp when the signals flashed individually and pressing his left hand on the key positioned to the left of the lamp when the same pair of lamps flashed.

The short series of signals, produced separately or in pairs of flashes ("individual lamp-individual lamp" and "pair-pair") were designated as the same stimuli series; if one of the signals was flashing individually and another signal was flashing from paired lamps ("individual-pair" and "pair-individual") then the stimuli series was designated as different.

The principle method, the meaning of which will be clear from further explanation, consisted of the fact that the second signal of both forms of the series could flash either in the same lamp or from another lamp on the panel. Given constant visual fixation by the subject on the spot, located in the center of the panel, the second flashing of the lamp led to visual afferentiation which begins in the retina and ends in the higher cortical structures of the visual region of the brain. Eight experimental variants were conducted.

All the variant series were presented to the subjects 10 times in random order at intervals of 10-12 seconds. All lamps on the panel were flashed a uniform number of times.

The time of each motor reaction by the subject as well as erroneous reactions were recorded. Ten subjects, between the ages of 20-35 years, took part in the study.

Experimental results

We examined the process by which erroneous reactions appeared in response to flashes from different lights which the subject responded

to with the left hand and in response to flashes from the paired lamps with the right hand. The subject was required to press the key with the right hand when the same flash appeared and press the other key with the left hand when paired flashes were shown.

Analysis of erroneous reactions indicated that they occur both for the first and for the second signal in all the series (table 1, I and II columns). However, statistical analysis, according to Styudent's criteria, showed that the quantity of erroneous reactions to the second signal was significantly greater than the first signal ($P < 0.01$). These data point to the presence of certain factors which have an influence on the accuracy of performing the second motor reaction in each series and are related to secondary reactions in the nervous structures which carry out the first reaction. In order to explain these factors it is necessary to carry out a differential analysis of erroneous reactions to the second signals in the different and same stimuli series. We found that erroneous reactions to the second signals occurred both in thecase of the presence of both lamps with the first signals and in the absence of both lamps in both types of stimuli. In columns III-VI in table 1, the distribution of erroneous reactions is presented. Note the large number of mistakes (8.6 of the total) exhibited in reaction to the second signals (different stimuli) and the large number of errors (30.5 percent) seen for the same stimuli (first signals) (column VI). As is evident from the table, these two groups of mistakes are responsible for the large number of erroneous reactions to the second series of signals.

Discussion of Results

The two groups of erroneous reactions occur as a result of the second signals: in the different series of stimuli provided by all lamps, and in the same series of stimuli with the absence of all lamps. There is a tendency to react to the second signal with the same response as to the first if it is displayed with the first signal from all the lamps. Less apparent is the other tendency to react to the second signal if both lamps in both series are absent.

We examined in detail, the tendency of the first type leading to the appearance of erroneous reactions to different signal series in an earlier article (9). In this article we will only consider it when the reaction appears after perception of the first signal in the different series. We examined the performance of the corresponding motor reaction along sensory motor pathways which participate in the production of the impulse for stimulation by the first signal. The sensory impulse tends to be extended prior to the stimulation course and to actualize the motor program

Таблица 1

РАСПРЕДЕЛЕНИЕ КОЛИЧЕСТВА ОШИБОЧНЫХ РЕАКЦИЙ В ПОСЛЕДОВАТЕЛЬНОСТИ СИГНАЛОВ

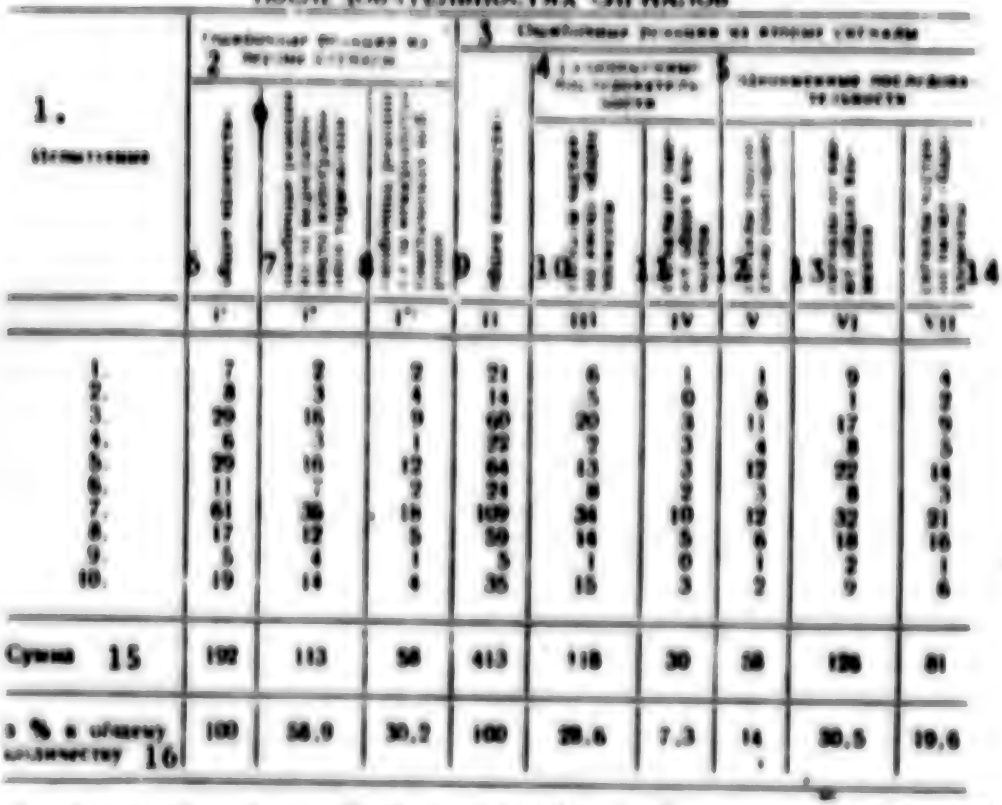

Table 1. Distribution of the quantity of erroneous reactions in the signal series

Key:
1. Subject
2. Erroneous reaction to the first signals
3. Erroneous reactions to the second signals
4. Different series
5. Same series
6. Total number
7. Erroneous reaction because of inadequate integration of inhibition
8. Erroneous reaction because of "immunity" of gnostic neurons
9. Total number
10. Signals which have a partial number of all the elements
11. Signals which do not have all elements
12. Signals which are completely matched
13. Signals which do not have all elements
14. Signals which have a partial number of all the elements
15. Total
16. Percent of total number

which corresponds to the first signal. To perform the first reaction to the second signal this tendency must be inhibited and a command impulse to realize an adequate motor program must be sent.

This neuro-dynamic process usually determines the time period for the right reaction to the second signal of the different series issuing from all lamps for the first signal (8). In our opinion, integrated inhibition plays a co-ordination role in the accomplishment of acts of higher nervous activity and serves as a regulator of such neuro-dynamic rearrangements (9). If the inhibitory process is not sufficiently strong then erroneous reactions occur. Thus, erroneous reactions of this type arise as secondary reactions in the nervous structures which perform the initial motor reaction.

To analyze the mechanism of the erroneous reaction to the initial signal series (table 1, column I), we showed that suppression of the majority of these errors (58.9 percent) occurred in a specific and regular pattern as a result of secondary reactions in the nervous structures influenced by inadequate integrational inhibition (column I). Here, the secondary effect was significant because the time interval between the series of two signals in our experiment was 10-12 seconds. Evidently, this interval is not adequate for effective attenuation of the stimulation which succeeds the effects of the second stimulus from the preceeding series.

We studied the above described tendency of the second type which conditions the occurrence of the erroneous reaction to the similar series of stimuli when all lamps are absent.

The distribution of errors for the second signals in the similar series (table 1, column V and VI) indicates that in the case of absence of all lamps, the number of erroneous reactions significantly increases ($p<0.01$). Our hypothetical explanation for this form of erroneous reaction is based on the theoretical conception of Yu. Konorski concerning the physiological mechanisms of perception (5). The basic position of this theory is a concept about the existence, in higher sections of the afferent system, of special neuronal formations--gnostic neurons--which are responsible for simple or very regulated (unitary) forms of perception. This process by which gnostic neurons are formed arises with the appearance of a new pattern of influence by a strong orientation reaction which activates the gnostic field. Because of the activation of the gnostic neurons, the potential synaptic connection is transformed into action. Consequently, when this again appears as a pattern, it will activate the same neurons as when it corresponds to the unitary perception in the given gnostic field. An important part of the theory of Yu. Konorski is the fact that the new pattern of stimuli can lay claim not only to the "non-involved" neurons of the gnostic field, but also to neurons which are transformed as a consequence of these patterns. This is the principle of "immunity" of the functioning gnostic neurons against "foreign" patterns.

In addition to these concepts which are the basis of the theory of Yu. Konorski, it is necessary to include the following. When selection of alternative answers requires the subject to perform different movements of the hand, both reactions can be simultaneously prepared in advance; that is both motor centers can be found in a state of heightened excitability. After performance of the first reaction, the whole nerve pathway, activated by the preceeding signal for a motor response, is found in a state of increased excitability.

We now use this position for a hypothetical explanation of the mechanism for occurrence of a tendency to perform various motor reactions.

In tests we presented the same series of signals "similar lamp-similar lamp" (figure 1). After appearance of the same flash (a') the nerve pathway is activated by the signal and the corresponding motor centers were found in a state of increased excitability. If as a consequence of this the same flash is presented to a different place in the visual field (a") activating another section of the network and brain structures, the nervous impulse must still reach the same group of gnostic neurons which respon d to the perception of the similar flash and according to Yu. Konorski, which respond to each perception of a defined object (in our case-the same flash). But, in so far as these gnostic neurons are still not completely liberated from the transformation of the sensory flow which occurred as a result of the action of the first signal, they become "immune"; that is insensitive to the effect of "its own" pattern arising from perception of another similar flash. If stimulation from the same flash in the pathway towards its motor center is somehow hindered (in this case-the temporary "immunity" of the gnostic neurons), then a tendency occurs for directing the nervous impulse towards foreign gnostic neurons or towards other stimulating motor centers which actualize the motor program corresponding to the perception of the paired flashes (b). This is how the foreign motor program is realized and the erroneous reaction performed.

Our interpretation of the mechanism for erroneous reactions to the same signal series is confirmed by the data of statistical analysis of the time reaction (TR). In table 2, these data are presented pointing to the fact that the TR for the same signal which follows the paired signal is shown to be significantly shorter than the TR for the same signal which follows the same signal ($P<0.05$ according to the non-parameter criterion of Vander-Varden; in this analysis, we only considered the signal series which did not come from all lamps). Analogous results were obtained in relation to TR for the paired signal. TR of the subjects to the paired signals which followed the same signal on the whole for

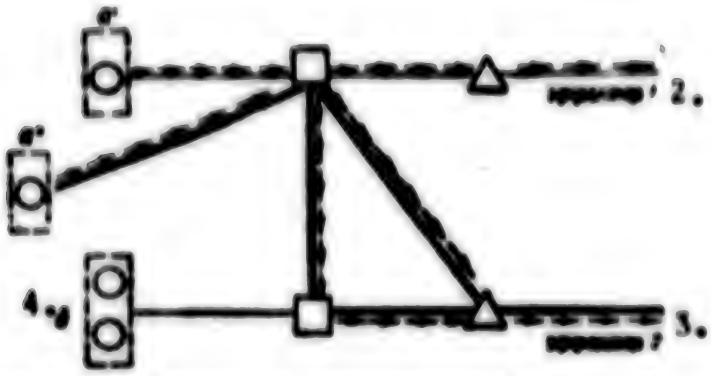

Рис. 1. Схематическое изображение механизма возникновения ошибочных реакций в одноименных последовательностях:

1. квадрат – высшие отделы зрительного анализатора, треугольник – центральная часть двигательного анализатора. Стрелками показан поток эфферентно-афферентных импульсаций

Figure 1. Schematic representation of the mechanism for stimulating the erroneous reactions in the same signal series

Key:
1. Square-higher sections of visual analyzer; triangle-central part of motor analyzer. Arrows show the flow of afferent-efferent impulsation.
2. Effector 1
3. Effector 2
4. B

Таблица 2

СРАВНИТЕЛЬНЫЕ ВР НА ВТОРЫЕ СИГНАЛЫ В ОДНОИМЕННЫХ И РАЗНОИМЕННЫХ ПОСЛЕДОВАТЕЛЬНОСТЯХ СТИМУЛОВ, НЕ ИМЕЮЩИХ ОБЩИХ ЭЛЕМЕНТОВ (количество случаев)

1. Испытуемые	2. ВР на одинаковую вспышку после первой по сравнению с ВР на вторую вспышку после различной вспышки			3. ВР на вторую вспышку после одинаковой по сравнению с ВР на вторую вспышку после первой вспышки		
	4. равенство	5. деление	6. кратно	4. равенство	5. деление	6. кратно
1.	5	2	4	1	5	5
2.	0	5	6	2	6	3
3.	1	4	6	1	5	5
4.	1	2	8	1	5	5
5.	1	1	9	1	4	6
6.	0	3	7	1	3	5
7.	0	2	7	0	4	5
8.	0	4	5	2	3	4
9.	0	0	9	1	2	6
10	0	3	8	0	2	9
7. Суммарное количество случаев	8	31	68	10	39	53

Table 2. Comparative time reaction to secondary signals in similar and different signal sequences comprised of different elements (number of cases)

Key:
1. Subject
2. Time reaction to similar flashes after the first in comparison to reactions for similar flash after the same flash
3. Time reaction to paired flashes after similar ones in comparison with reaction to paired flashes after the first flash
4. Congruence
5. Prolonged
6. Short
7. Total number of cases

the group of subjects were shorter than TR for the paired signal which followed a paired signal. However, in this case, there was a non-uniformity of selection in the results obtained suggesting only a certain analogous tendency.

Thus, the statistical analysis of TR indicates that in the case of absence of all lamps, the motor reaction for the second signal in the different series is performed significantly faster than in the same signal series: the reaction to the second signal of the same series which does not have all the lamps from the first is somewhat more difficult as seen in the increased absolute significance of the corresponding TR. Evidently, the difficulty is the "immunity" of the effected gnostic neurons.

We feel that our theoretical position concerning immunity of the gnostic neurons is confirmed by the neurophysiological data on the character of impulse activity of neurons which go with the relatively elementary conditioned reflex form of memory (6), (7). It has been found that after the transmission of the stimulation impulse a period of no electrical transmission between the given neurons transpires. The subsequent impulsation takes a different course to different neurons, the excitability of which is heightened at this moment.

Turning again to the analysis of erroneous reactions which occur in response to the first signal series and the theory of the regular nature of their pattern, one can assume that the mechanism of "immunity" of the gnostic neurons determines 30.2 percent of erroneous reactions (table 1, column I). In fact, an insignificant number of erroneous reactions-10.9 percent was found.

Thus, we formulated the following concept about the function of gnostic neurons which leads to the phenomenon of patterned erroneous reactions in situations of sensory-motor interaction. The effect of the first signal in the series of stimuli leads

to formation of a certain dynamic functional system which encompasses specific localization of a given visual stimuli in the network leading to the nerve pathways and gnostic neurons answering the perceived signal. This process of stimulation forms an additional functional system. In the case of the presentation of the second, alternative signal which stimulates other parts of the network, a new dynamic functional system is added which depends on the first. Hence the patterned erroneous reaction is not observed. The tendency to perform the same reaction leading in a series of cases to the appearance of erroneous actions occurs when both signal series have all elements present. The two series of signals stimulate partially or completely the same part of the network. Actually, if in the case of different series of signals the second signal is shown by both lamps with the first signal, then the partial presence of both inputs leads to a more complicated dynamic functional system which responds to perception of the first signal; the actualization of the response leads to the erroneous reaction. On the other hand, in the absence of both inputs, the tendency even for response by different reactions to the same signals occurs. Thus, given presentation of the same signal series, in which the signals do not have all inputs, stimulation is caused by virtue of the "immunity" of gnostic neurons.

Thus, when the signals are comprised of all elements a more complex dynamic functional system is initiated which leads in a certain number of cases, if it is not suppressed, to a repeat of the motor reaction just performed. If all elements are not in the input, then the process of stimulation forms a new dynamic functional system which includes other gnostic neurons participating in the performance of alternative motor programs.

Another group of data cofirm our argument. In the similar signal series (pair-pair), the second pair of flashes could include either one of the lamps just flashed in the first paired signal or both lamps. Thus, if our assumption is correct, one ought to expect that the number of erroneous reactions in the same series will diminish with the increase in number of flashes from both lamps. Our data confirm this assumption. As is evident from table 1 (column VI), the total number of erroneous reactions given the absence of both lamps is equal to 126; given one of the lamps--81; and in the absence of two of the lamps--58. An increase in the number of both elements in the input strengthens the tendency for a response with the same hand and increases the probability of accomplishment of the correct motor reaction.

The dynamic functional system, which is complicated as a result of the transmission of stimulation impulses, is initiated by a signal which gradually attenuates with time. The immunity of

Рис. 2. Зависимость среднего количества ошибочных реакций на вторые сигналы одноименных последовательностей при отсутствии общих элементов с первыми сигналами от межстимульного интервала (средние данные 10 испытуемых)

Figure 2. The relationship of the average number of erroneous reactions to the second signals of the same series given absence of all elements from the first signal at interstimuli intervals (average data from 10 subjects)

Key:
1. Average number of erroneous reactions
2. Time in seconds

gnostic neurons will weaken, leading to a decrease in the number of erroneous reactions to the same series for the second signals comprised of all lamps from the first. In figure 2, a graph is presented showing the average number of erroneous reactions of this type in terms of time intervals between signals in the same signal series. The tendency for a decrease in the number of erroneous reactions given an increase in the interstimulus interval is evident.

The mechanism which we described for the stimulation of erroneous reactions answers certain questions on the nature of psychological refractivity (2), but has a significantly more complex internal nature and has less in common with the refractivity of nerve fibers.

Conclusion

In this article, we examined the psychophysiological mechanisms in conditions of sensory motor interaction of a tendency to accomplish the same motor reaction for different signals when all elements (lamps) are present, but different motor reactions were performed for the same signals when all elemnts are absent. This leads, in a number of cases, to performance of erroneous reactions. As was shown in this study, one can assume that the cause of these erroneous actions performed by the subject are the result of stimulation of the nervous structures which participate

in the performance of the first motor reaction. This reaction, only arising in the nerve structures which perform the second motor reaction, is the cause of a large number of erroneous reactions which appear in response to the presentation of the first signal of the next stimuli series when the interval between them does not exceed 10-12 seconds.

From our point of view, both tendencies for these reactions are similar in the relative localization of the second stimulus in the network. Thus, the tendency to respond with the same hand to two different stimuli occurs with repeated stimulation of already excited areas of the network and the projective brain structures. On the other hand, given stimulation of other parts of the network and projective brain structures, the tendency for response by different hands occurs.

The results described in this present study on the mechanism for erroneous reactions provide a differential analysis of the inertness of nervous processes.

In conclusion, it is important to note the practical significance of results of such a study on the psychophysiological mechanism for erroneous reactions which occur in conditions of sensory motor interaction. These data elaborate the principles for using such signal series in a system of induction for the organization of activity in systems of management, in various forms of working activity and for experimental psychophysiological studies.

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PROSPECTS FOR DEVELOPMENT OF METHODOLOGY OF ERGONOMICS AND ENGINEERING PSYCHOLOGY IN THE USSR

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[Text] The solution of complex problems of interaction between social, natural and engineering sciences is the methodological prerequisite of ergonomics as a scientific discipline. These problems arise, not only in connection with definition of their objects and subjects of study, but because of interpenetration of their conceptions and methods. The distinctive feature of modern applied scientific research is that it is interdisciplinary, i.e., complex. There is also another distinction: these interdisciplinary studies themselves become stable and acquire their own tradition. They deal with development of invariant procedures and methods and, on the theoretical level, with stable conceptual schemes that substantiate the use of the procedures and methods, and lead to systematization of formation of special, specific knowledge, with ultimate appearance of a new scientific discipline. This is the situation not only in ergonomics,

*An abridged version of the article in the collection entitled "Problems of Methodology in Ergonomics" ("Trudy VNIITE. Ergonomika" [Works of VNIITE. Ergonomics], No 17, Moscow, 1979. The collection is dedicated to Aleksey Nikolayevich Leont'yev (1903-1979)

**Author of works on child and age-related psychology, pedagogics, methodological problems of psychology.

***Author of works on engineering psychology, ergonomics, methodology of psychological research.

****Author of works on ergonomics and engineering psychology.

but in a number of allied disciplines generated by the scientific and technological revolution--esthetics in engineering, systems analysis, control theory, etc. The thesis of A. Leont'yev, formulated in the context of analysis of the intensive development of interdisciplinary research, which links psychology with neurophysiology, cybernetics and logical mathematical disciplines, sociology and the history of culture, applies fully to ergonomics. He wrote: "Of course, scientific synthesis of heterogeneous complexes of psychological factors and generalizations cannot be achieved by simply putting them together in the same book [binding]. It requires further development of the conceptual system of psychology, a search for new scientific theories capable of tightening the loose seams in the building of psychological science."[1]

In the situation of appearance of new directions of scientific searching, when various programs and plans are being constructed for them, the importance and weight of methodological work proper are increasing. It must be noted that its forms change with the development of the corresponding discipline (in this case, ergonomics and engineering psychology), reflecting the vital needs of both applied research and its general conceptions.

It is important to bear in mind the following important circumstances.

At the present time, a substantial change is taking place in the correlation and methodological role of basic and applied psychological research. We have still retained the habit to conduct applied studies and derive conclusions from them on the basis of the persistent psychological concepts that were formed several decades ago. Up to a certain time this was alright. But, occasionally we overlook the fact that it is expressly within the framework of concrete applied studies that far from trivial characteristics of performance, consciousness and personality of an individual appear and take shape. Expressly they can and should become the springboard for new theoretical ideas and concepts, which remove the special aspect of applied conclusions and lend them a general psychological meaning. At the present time, one of the most important conditions for development of general psychology is to pay attention to applied studies.

In our opinion, an example of this is an aggregate of ergonomic data that permits specific and methodologically confident overcoming, at last, of the set of functionalism, both classical and updated, that is deep-rooted in psychology. It is expressly in the stream of industrial psychology and ergonomics that the meaning emerges, in all its concrete scientific significance, of the concept of "integral activity of a subject," which is used to solve relevant vital problems. The use of the concepts of "activity" [performance], "type and forms of activity" makes it possible to rationally inscribe the characteristics of separate, so-called mental functions in the general flow of ways and means of providing for man's social life. It is only within the element of this life, theoretically formulated in concepts of activity and its concrete forms, that one can

weigh and assess the real share of some functions or other, and furthermore determine their actual content and correlations.

* * *

The scientific works of A. Leont'yev, which are also of substantial significance to the development of ergonomics, hold an important place in the development of methodological and theoretical bases of engineering psychology. As far back as 1962, in a work he wrote with D. Panov, there was comprehensive discussion of the status and tasks of psychology. The main directions of research in engineering psychology, which subsequently became part of the range of scientific interests of A. Leont'yev, were outlined there. This work can be classified with those that develop the theses of psychological theory of activity. Many of the problems posed in it were subsequently developed and defined in the collective monograph, "Engineering Psychology" (Moscow, 1964). It was stressed in these works that, in the theoretical aspect, the "man-machine" problem emerges as a problem of the basic correlation between processes performed by a machine and man's activity as the subject of labor. In this regard, we should like to call attention to the fact that it is expressly in the study of the "man-machine" problem that psychology is most acutely confronted with the general psychological task of making a precise distinction between formalized and unformalized elements of human activity, the difficult task of searching for the patterns of constant change in correlation between these elements when developing and introducing more and more new man-machine systems.

The monograph of B. Lomov, "Man and Technology. Essays on Engineering Psychology" (Leningrad, 1963) played an important part in systematizing and analyzing the experimental material gathered by engineering psychology. In this monograph, this branch of knowledge is characterized as both an engineering and psychological science. The task for the latter includes the study of mental processes and properties of man in order to determine the specifications for work tools and technology that ensue from the characteristics of these processes. In the monograph of B. Lomov, the problems and tasks are formulated that have potential significance, which are related to the complex study of man, his work, cognition and communication. "The problems that arise in connection with analysis of human performance as an element in a control system are, in essence, on the borderline of psychology, various branches of cybernetics and a number of other scientific disciplines. Solving them would require complex studies " (p 246).

The main principles involved in theoretical analysis of problems of engineering psychology and ergonomics on the basis of expounded conceptions of development of the psyche and psychological structure of activity were described by A. Leont'yev, in "Man and Automation" ("Psychological Studies," No 2, Moscow, 1970). It provides methodological substantiation of the decisive role of development of the means of solving applied problems in basic research and psychology.

The first Soviet publications dealing with ergonomics, which discussed its subject and tasks, its interrelations with other areas of scientific and practical endeavor, appeared, as we see, in 1963-1964.[3] Methodological questions of inception of ergonomics as a scientific and planning discipline were discussed by B. Lomov. Among its basic elements, determined by the important aspects of interaction between man, machines and the environment, he mentions engineering psychology which deals with the process of informational interaction between man, machine and environment. "Unlike the specialized sciences dealing with labor, ergonomics does not examine working man by himself, a machine by itself or the working environment by itself, but expressly a 'man-machine-environment' system."[4]

A special work by V. Rozenblat deals with definition of the subject of ergonomics and its relation to other disciplines. He derives there the general conclusion that "Ergonomics is a synthetic discipline concerned with adaptation of work and the tangible environment to man. It generalizes the applied sections of a number of disciplines that deal with the human factor in labor (anthropometry, industrial physiology, industrial psychology, industrial hygiene, esthetics in engineering) and develops complex recommendations for designers to improve the tools of labor, working conditions and work actions, as well as consumer goods to conform with the capabilities and distinctions of the human body."[5]

A. Leont'yev attributed much importance to the formation of ergonomics as an area of scientific and practical endeavor. The close scrutiny given by A. Leont'yev and other psychologists to the development of ergonomics is the consequence of profound understanding of the vital problems of psychological science. The growth in technological equipment in industry due to the scientific and technological revolution, renders man's activities more complicated. "Under such conditions, mental and psychological development of man becomes the most important reserve for increasing the social productivity of labor, while the 'human factor' becomes a special gage of the entire process of developing and operating new technological equipment. Consideration of this factor in industry is of great national importance, it is an urgent requirement of the scientific and technological revolution. Specialists in psychology are called upon to help solve this problem."[6]

The theoretical research of A. Leont'yev and his organizational talent were instrumental in transforming ergonomics from a scientific movement brought to life by the current scientific and technological revolution into a scientific discipline. Let us mention that he was one of the organizers of conferences of scientists from CEMA member nations dealing with ergonomics.[7] While preparing for the first of these conferences, A. Leont'yev made a retrospective analysis of the main aspects of ergonomic problems from the standpoint of Marxist theory of activity. This analysis was the conceptual basis of the first generalizing consideration of methodological problems of ergonomics in the Soviet literature.[8]

In this work, the principles were outlined for developing problems of ergonomic methodology. In particular, it was noted that the approach to man as a special element in a system of automatic devices and machines makes it possible to solve some important problems pertaining to improvement of the efficiency of this system. At the same time, attention was called to the limitations of the approach that abstracts itself from the social nature of man as the subject of activity, a circumstance that cannot be overlooked, not only when working on broader theoretical problems, but within the framework of the man-machine problem. In this book, the thesis of two directions of research in ergonomics, corrective and projective, was developed on the basis of the activity-related approach.

For a long time planning [design], which is one of the methods in practical engineering, was alien to psychology, since it strived to study "natural" mental processes. The method of observation, natural and laboratory experimentation demonstrating the existing capabilities of man were inherent in it. But then some substantial changes took place, first in age-related and pedagogic psychology, then in other of its branches. In the 1950's-1960's, the idea and method of formative or teaching experiments became popular in the USSR. They were conducted in child psychology in the mainstream of the basic thesis of L. Vygotskiy concerning developmental teaching. In subsequent years, there was ever increasing disclosure of the theoretical bases of such experiments, which served as the foundation for the genetic-modeling method. Concurrently, analogous ideas started to crop up in the field of industrial psychology and ergonomics also. In essence, they consist of planning and active checking of the degree of efficiency of new forms of activity of a subject in solving some practical social problems in the area of instruction and labor. Merging of processes of planning, forming and examining activity, consciousness, personality--such is the general set of the school of L. Vygotskiy, A. Luriya and A. Leont'yev, which was successfully developed in the works of P. Gal'perin, A. Zaporozhets, D. El'konin and others. More active use of this set in the field of industrial psychology and ergonomics is the pressing task for these disciplines at the present time.

The thesis of planning human activity in control systems has an important methodological function in ergonomics and engineering psychology. The development of the idea of planning external and internal means (methods) of human activity in control systems was linked with the tradition of the school of L. Vygotskiy, its concepts of interiorization and exteriorization of higher mental functions, analysis of symbolic systems and tools of activity.

Complex study of the question of man and his work activity is important to the formation of ergonomics. The psychologists and sociologists of Leningrad University are making a substantial contribution to development of the methodology of such studies. The results of research conducted there were reflected, in particular, in the monograph of B. Anan'yev, "On the Problem of Modern Science of Man" (Moscow, 1977), in which the

importance of ergonomics to general theory of science of man is stressed. The special approach to technology, as a set of amplifiers, transformers and accelerators of psychophysiological functions of man, is also linked with ergonomics.

Methodological problems of formation of the complex approach to the study of work activities were the subject of special consideration in a number of works.[9] An effort was made to provide methodological substantiation of the complex approach to the study of quality of work under conditions of developed socialism. Quality of labor is construed as the integral characteristic of a given type of labor, which includes quality and quantity of output as related to expenditure of labor, psychophysiological and physiological price of activity, as well as health and development of the worker's personality. The correlation and mutual determination of the above elements form an integral system of the quality of a specific form of labor, and it has a multilevel structure. Determination of the indicators of quality of labor implies that the obtained data about its different components are related to knowledge about the quality of labor as an integral system.

Methodological problems of development of ergonomics, which were related to the developing trend to turn from accumulation of numerous, often disparate facts about different aspects of human activity to creation of an integral theory of planning activity, began to be discussed in the late 1960's and early 1970's. Social aspects of ergonomics began to attract special attention. In this connection, there was substantiation of the thesis that, under conditions of socialist production, the subject of studies in ergonomics should be the "group-man-machine" system, rather than the "man-machine" system.[10] It was stressed that ergonomics performs not only an economic function, but a social one, since it sets as its main task the creation of favorable conditions for increasing labor productivity, assuring safety and convenience for workers, conditions that help safeguard their health, develop their intellectual and physical qualities.

The cycle of articles by A. Leont'yev, published at different times in the journal KOMMUNIST, was of basic importance to the development of industrial psychology, engineering psychology and ergonomics. It was noted in one of them that the complete psychological content of the problem of man and machine is disclosed only if "one proceeds from the fact that creation of tools and machines is a process of implementing with them the transformed functions of man; that machines are, in the expression of Marx, 'organs of the human brain created by human hands,' with which man relegates performance of operations constituting his activity, which are beyond his capabilities as a whole because of the required expenditure of energy or required rapidity."[11]

His profound comprehension of the patterns and specific conditions of development and use of engineering psychology enabled A. Leont'yev to define, already at the early stages of its formation, the most promising

tendencies for development of this new branch of science. The first consists of relative intensification of research on the most complex processes of man's mental activity, that which distinguishes basically the capabilities of man from those of a machine. In this regard, a new direction of development of engineering psychology acquired importance; it deals with research in the area of flexible [current] thinking (for example, the works of V. Pushkin). Another tendency is, in the opinion of A. Leont'yev, related to a change in methodology of developing man-machine systems. While formerly, in developing such systems, planning of a control system as part, first of all, of its technical elements was the starting point and man is included in it as a technical element, in the future man and his task will be the starting point of planning. All of the technical elements of the "machine" system will develop as an aggregate of "artificial organs" servicing man's activity.

The complex approach inherent in interdisciplinary research became one of the typical features of ergonomics as well. Its theoretical outline as a special branch of scientific and practical endeavor was described rather definitely in a cycle of works. In them, ergonomics is described in a number of its man aspects: goals and tasks, general conception reflecting the specific traits of socialist economy, link with allied industrial sciences, specifics of work in control systems, techniques for ergonomic research and planning, change from corrective to projective ergonomics, etc.[12]

Efforts at comprehensive descriptions of the link between ergonomics and other sciences were made in a number of special works which studied, in particular, problems of correlations of ergonomics, engineering psychology and systems analysis.[13] Development of systems analysis provided greater methodological clarity to solving problems of ergonomics itself. This is attributable, first of all, to the circumstance that the main objective in engineering systems is considered to be to arm the operator with the best engineering and technological equipment and, with it, to provide comfortable conditions for him, to enable him to make reliable diagnoses, to make and implement decisions. Efforts to completely formalize the control process in complex man-machine systems appear fruitless to us, since the creative element will always be the main work in such systems.

Several works published in the 1970's deal with the main methodological problems of engineering psychology and ergonomics, with their applied problems in the area of reception and processing of information by an operator. Here, special attention is devoted to analysis of the basic concepts in this branch of knowledge, in particular the bases of psychological theories of activity, shedding light on the most effective means of studying operator performance, methods of evaluating man's condition under different working conditions, problems of teaching and determining professional fitness, as well as some questions of planning and standardization in the field of ergonomics and engineering psychology.[14]

Work on methodological problems pertaining to the general prospects of development of scientific disciplines, on the borderline of which it emerged, was very important to the formation of ergonomics. In particular, analysis of theoretical problems of industrial physiology enabled V. Medvedev to draw the following methodological conclusion of importance to ergonomics: "There is every reason to believe that the tendency now evident to integrate a set of sciences dealing with human behavior in the course of activity will dominate in the next few years over the entire course of scientific and applied work, i.e., the ergonomic approach will be the leading one."[15] Methodological analysis of studies of operator performance during space flights made it possible to formulate quite definitely the thesis concerning the object of ergonomic study: "In the course of a study a third object must necessarily appear, which the researcher encounters the most often, i.e., the structural links between the object and the environment, between man and machine. When studying the main problem of ergonomics, the man-machine problem, the most attention is given to expressly this fact.[16]

Recently, a series of works was published, which deal not only with theoretical and methodological problems at the current stage of development of ergonomics and engineering psychology, but with an attempt to systematize them.[17] The systems approach in ergonomics and engineering psychology has been submitted to a deeper interpretation.[18] Use of the principles of structural-functional and microstructural analysis of activity made it possible to single out different types of structures of activity (rigid, self-adjusting, self-organizing) and to consider the possible means of their formation and operation. At present, it is already becoming obvious that the principle of hierarchic organization of activity is inadequate, and that it must be supplemented with the principle of heterarchic, or coalitional organization (since activity, like consciousness and personality, is polyphonic). Both stability and lability of activity are provided by combining the heterogeneous components and structures into heterarchic coalitions, which are formed and disintegrate in the course of development and operation of activity (as its goals are changed and new ones are set, depending on current external and internal conditions).

Continued development of antireductionistic and antimentalistic conceptions of mental activity, disclosure of functions that generate it, analysis of time and space properties as acts of activity proper, as well as new mental formations and constructions generated as a result of these acts, was also very important to ergonomics.[19]

Analysis of the main problems of ergonomics, which is contained in one of the editorials in KOMMUNIST, was important to effective development of methodological problems of ergonomics. It is stressed there that "The subject of scientific research in the area of labor is not only equipment [technology] by itself and not only man as the subject of production, but coordination of his physical and mental capabilities, esthetic taste and other social traits with the properties of modern engineering systems."[20]

It is stated in that article that when organizing complex research one must be well aware of the fact that the meaning of this research does not lie in studying the same subject from different aspects and to describe the information gained about it, but primarily in singling out the main systematizing factor that determines the specifics of the system under study, its integrity. As applied to ergonomics, this means that an effective solution to problems thereof is possible only if synthesis of social and natural sciences will base itself on general theory of work activity, rather than be directed along the route of mechanical joining of data in one or the other of them into a certain summated system or conglomerate of knowledge, or along the route of their "mutual subordination."

At the present stage of development of industry, it is further noted in the editorial, it is becoming possible to technically execute plans based on a generalized and integral conception of human activity. Basically new reserves for increasing the efficiency of labor are disclosed when one proceeds, in developing an engineering assignment, from the idea of secondary, servicing function of machines and, consequently, one takes into consideration, first of all, the positive qualities of man as the real subject of labor, i.e., that which constitutes his advantages over machines. In the future it is planned to turn from solving urgent problems of organization of labor, refinement of existing technology, adaptation of man to already existing technological norms, to the planning of new forms of human activity on the basis of complex theoretical study of potential physical, psychological and intellectual capabilities of man, with which ergonomics is already dealing.

* * *

As shown in the above brief survey of the most important Soviet works dealing with theoretical and methodological problems of ergonomics (and engineering psychology), the principle and category of activity emerge as its central foundation. This category "operates" differently for different authors: for some as an explanatory principle, for others as the subject of research, for others yet as the subject of organization, control and planning. There are also differences in degree of stratification [division] of conceptions of activity, ranging from rather global conceptions to conceptions of its functional structure and microstructure. At the same time we observe some real difficulties in using the category of activity and its different conceptual schemes in ergonomic theory and practice.

As we have indicated above, activity is the subject of both intradisciplinary and interdisciplinary research. Much attention is being given to analysis of activity in modern and, first of all, Marxist philosophy, social sciences and psychology. Anthropology, ethnography, linguistics, and later on biomechanics, human physiology and cybernetics made a significant contribution to development of the corresponding aspects of human activity. And yet, the status of this problem or, more precisely, its

reflection in special sciences and correlation between different sciences in formulation and solution thereof, cannot be considered adequate.

We are convinced of this, in particular, by the fact that psychology by no means always bases itself on the experience of philosophical analysis of activity. In the disciplines dealing with work activity and in the pedagogic sciences, the advances not only in philosophy, but psychology are not taken into full consideration by far. And we are not dealing here with the natural lag as related to present advances. There are basic differences and difficulties in interpretation of the very concept of human activity, in the choice of bases for classifying the forms thereof, in creating taxonomic units intended for analysis thereof, in the choice of adequate methods of studying it under both laboratory and natural (industrial, educational) conditions, in comparing the results obtained by different methods, both to one another and to the categorial system developed in the historic-philosophical tradition of studying activity. All this leads to new difficulties and, at times, naive formulation of problems, confusion, underestimation and overestimation of the significance of the results obtained in some theoretical and practical area.

As an illustration of these difficulties, we shall offer a far from complete list of the distinctions made between forms and types of activity, which exist in modern science: material and spiritual, external and internal, direct and mediated, voluntary and involuntary, conscious and unconscious, individual and collective, reproductive and creative activity, game, educational work, athletic, cognitive, performing [executive], perceptual, mnemic, mental activity, etc. To these distinctions is added differentiation of activity according to motive, goal, subject, means of performance, end result, etc.

As we see from this list, each individual form of activity can be described by means of many reference systems that actually characterize it. At the same time, it is customary to believe that applied research problems can be solved much more easily when one uses the same, be it primitive and unilateral, but clearly defined dimension. On this basis, one often uses characteristics that are external in relation to activity in order to analyze it (for example, amount of information, speed, accuracy, expenditure of energy, etc.), without sufficient consideration of its polyphonic nature and its inherent, immanent properties. In spite of the high reliability of results obtained from such a study, this creates serious difficulties with regard to interpreting them, extrapolating them to other conditions, solving optimization and planning problems. The reason for this is that living acts of human activity are replaced with facts, in which activity as such disappears, it "dies in the product." For this reason, the most important methodological problem that must be solved when studying activity is to provide for theoretical and methodological preservation of its main characteristics as a result of the study. In other words, it is necessary not only to study the means

or image of activity, but to build the image of expressly a studied form of activity. Only then can the obtained results be used in situations other than those in which a given form thereof was studied.

In addition, it must be borne in mind that solving specific practical problems is related to the creation of different images, conceptions, schemes and models of the same activity. Thus, its algorithmic description would hardly satisfy a designer, although it is useful in solving the problem of distribution of functions in a man-machine system. Similarly, specific conceptions of activity are needed by specialists in the area of scientific organization of labor.

Modern Marxist science is faced with problems of construction of general theory of activity, further development of psychological theory of activity, specification of these theories as applied to various forms and types of activity (labor, education, games, etc.). Of course, there will be common elements in these theories, but one cannot underestimate the substantial differences between existing conceptions of concrete forms of activity and their future modifications and new variants. The solution to these problems cannot be speculative, nor can it be obtained solely through laboratory research.

The social and scientific conditions under which ergonomics appeared were such that conceptions of human factors and man-machine systems taken from technical and cybernetic constructions were the focus of its studies. They played a constructive role in a number of applied studies and in the course of development of ergonomics into an independent branch of science. But development thereof encountered limitations generated by natural scientific and engineering orientations. Something that was perceived by all as being quite important and essential remained beyond the realm of research and planning. This "something" is man himself, as the subject and main element of productive forces, seen not as a special type of mechanized device, not as a sort of cybernetic robot, but as a personality with its own goals, desires, i.e., that which spiritualizes a machine. And, as noted by A. Leont'yev, one must bear in mind here expressly the different activities of the subject, which are the initial "units of psychological analysis of the personality, rather than actions, operations, psychophysiological functions or units of these functions; the latter characterize activity, but not the personality directly."[21]

In our opinion, many of the objective tendencies of formation of projective [planning] ergonomics, as well as future methodological support thereof, are linked with development of expressly these pressing problems.

FOOTNOTES

1. A. N. Leont'yev, "Activity. Consciousness. Personality," Moscow, 1975, pp 74-75.

2. A. N. Leont'yev and D. Yu. Panov, "Human Psychology and Technological Progress," in "Materials for Conference on Philosophical Problems of Physiology of Higher Nervous Activity and Psychology," Moscow, 1962.

3. See also: S. G. Gellershteyn, "Ergonomics--the Ally of the Artistic Designer," TEKHNICHESKAYA ESTETIKA [Esthetics in Engineering], No 2, 1964. V. M. Munipov, "On the Ergonomic Bases of Artistic Design," TEKHNICHESKAYA ESTETIKA, No 10, 1964. D. A. Oshanin, "Industrial Psychology," in "Modern Psychology in Capitalistic Nations," Moscow, 1963, and others.

4. B. F. Lomov, "Ergonomics and Scientific Organization of Labor," SOTSIALISTICHESKIY TRUD [Socialist Labor], No 8, 1969, p 117.

5. V. V. Rozenblat, "On the Subject of Ergonomics," in "Methodological Problems of Ergonomics. Proceedings of First International Conference of Scientists and Specialists of CEMA Nations and Yugoslavia Dealing With Ergonomic Problems," Moscow, 1972, p 231.

6. A. N. Leont'yev and D. Yu. Panov, "Human Psychology and Technological Progress," p 74.

7. Concerning this collaboration see: V. Munipov, "Development of Scientific Bases of Ergonomic Standards and Requirements," OBSHCHESTVENNYYE NAUKI [Social Sciences], No 3, 1979.

8. V. P. Zinchenko, A. N. Leont'yev, B. F. Lomov and V. M. Munipov, "Methodological Problems of Ergonomics," "Methodological Problems of Ergonomics. Proceedings of First International Conference of Scientists and Specialists of CEMA Member Nations and Yugoslavia Dealing with Ergonomic Problems."

9. See, for example: V. P. Zinchenko and V. M. Munipov, "Ergonomics and Problems of a Complex Approach to the Study of Work Activity," "Methodological Problems of Studying Activity" (TRUDY VNIITE. ERGONOMIKA [Works of the All-Union Scientific Research Institute of Esthetic Styling in Engineering. Ergonomics], No 10), Moscow, 1977. B. F. Lomov and V. M. Munipov, "Problems of Complex Research on Work Activity," EKSPERIMENTAL'NAYA I PRIKLADNAYA PSIKHOLOGIYA [Experimental and Applied Psychology], Leningrad, No 8, 1977.

10. See: K. Platonov, "Group--Man--Machine," SOTSIALISTICHESKIY TRUD, No 3, 1970. K. Platonov and V . Dantlyak, "On the Social Aspect of Ergonomics," TEKHNICHESKAYA ESTETIKA, No 4, 1971.

11. A. N. Leont'yev, "Pressing Tasks for Psychological Science," KOMMUNIST, No 2, 1968, p 67.

12. See, for example: V. P. Zinchenko and V. M. Munipov, "Theory of Ergonomics," TEKHNICHESKAYA ESTETIKA, No 6, 1977. V. P. Zinchenko and V. M. Munipov, "Fundamentals of Ergonomics," Moscow, 1979. V. P. Zinchenko and V. M. Munipov, "Man and Modern Industry," KOMMUNIST, No 10, 1975.

13. See, for example: V. P. Venda and G. L. Smolyan, "Ergonomics and Systems Analysis," in "Methodological Problems of Ergonomics. Proceedings of First International Conference of Scientists and Specialists From CEMA Member Nations and Yugoslavia Dealing with Ergonomic Problems." A. I. Gubinskiy, "Approaches, Principles and Methods of Studying Man-Machine Systems," Moscow, 1975. "Engineering Psychology: Theory, Methodology and Practical Applications," Moscow, 1977.

14. See, for example: "Military Engineering Psychology," Moscow, 1970. A. A. Krylov, "Man in Automated Control Systems," Leningrad, 1972; "Methodology of Research in Engineering Psychology and Industrial Psychology," Leningrad, Pt 1, 1974; Pt 2, 1975.

15. V. I. Medvedev, "Theoretical Problems of Industrial Physiology," FIZIOLOGIYA CHELOVEKA [Human Physiology], Vol 1, No 1, 1975, p 27.

16. Ye. V. Khrunov, L. S. Khachatur'yants, V. A. Popov and Ye. A. Ivanov, "The Human Operator in Space Flights," Moscow, 1974, p 105.

17. See, for example: B. A. Dushkov, B. F. Lomov, V. F. Rubakhin and B. A. Smirnov, "Fundamentals of Engineering Psychology," Moscow, 1977. "Engineering Psychology," Kiev, 1976. M. A. Kotik, "A Course in Engineering Psychology," Tallin, 1978. V. M. Munipov, "Ergonomics," BSE [Great Soviet Encyclopedia], 3d edition, Moscow, Vol 30, 1978.

18. See: B. F. Lomov, "Means of Constructing Engineering Psychology Theory on the Basis of the Systems Approach," in "Engineering Psychology. Theory, Methodology and Practical Applications." E. G. Yudin, "The Systems Approach and the Principle of Activity," Moscow, 1978.

19. V. P. Zinchenko, "Set and Activity. Is a Paradigm Needed?" in "The Unconscious," Tbilisi, Vol 1, 1978. V. P. Zinchenko and M. K. Mamardashvili, "The Problem of Objective Methods in Psychology," VOPROSY FILOSOFII [Problems of Philosophy], No 7, 1977.

20. "Correlation Between Social, Natural and Engineering Sciences to Be Strengthened," KOMMUNIST, No 1, 1977.

21. A. N. Leont'yev, "Activity. Consciousness. Personality," pp 183-184.

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ALL-UNION SCHOOL FOR YOUNG PSYCHOLOGISTS

Moscow OBSHCHESTVENNYYE NAUKI in Russian No 3, 1980 pp 209-215

[Article by A. Gostev]

[Text] The First All-Union School for Young Psychologists was held from 5 to 15 December 1979 in Obninsk, Kaluzhskaya Oblast. Its immediate organizers were the Institute of Psychology, USSR AS [Academy of Sciences], together with the Central Council of Philosophical (Methodological) Seminars under the Presidium of the USSR AS, USSR Society of Psychologists and CC of the komsomol. About 150 young psychologists from 13 Union republics and 40 cities of our country participated in the work of this school. Prominent Soviet psychologists delivered papers.

The main emphasis in the scientific program was on methodological problems of modern psychology and problems of making practical use of psychological knowledge in public [social] practice. The program was separated into several sections: "Current Problems of Engineering Psychology," "Cognitive Processes," "Current Problems of Differential Psychophysiology and Neuropsychology," "Methodological Problems of Social Psychology" and "Problems of Child and Pedagogic Psychology." A total of 22 papers was delivered, and there were more than 20 seminars.

The sessions began with a paper by B. Lomov, corresponding member of the USSR AS, scientific administrator of the school, who offered a comprehensive analysis of pressing problems and trends in development of psychological science in the USSR. In particular, this speaker stressed that the needs of social practice are the decisive factor of such development at this stage. The basic difference in objective content of goals and tasks performed by psychological science between socialist and capitalistic societies was disclosed from party positions in this report. Under capitalism, psychology serves the ruling class, providing for "effective" exploitation of the human factor. In a socialist society, psychology is placed in the service of human labor; it is based on the principles of genuine humanism and social optimism.

The paper of B. Lomov touched upon a wide range of methodological problems of concrete psychological studies. In particular, he devoted much

space to the specifics of psychological experimentation. With reference to the fact that it is impossible to directly extrapolate the methods of natural experiments to the area of psychological research, B. Lomov stressed the need for psychologists to consider the subjective factor. As for the methdological armamentarium of modern experimental psychology, it must include such effective analytical means as the systems approach, which takes into consideration the many levels and many dimensions of the object of study. (It should be noted that discussion of specific problems with due consideration of the requirements of a systems approach was an inherent feature in most papers. Thus, in the paper of V. Ganzen [Leningrad], "Levels of Systems Approach in Psychology," an effort was made to apply the systems approach to general psychology, to systematize the main psychological concepts, as well as to differential psychology, for a systemic description of human individuality.)

More recently, B. Lomov noted further in his paper, with the growth of experimental research the acute problem emerged of the psychological scientific fact that is not directly comparable with psychological reality. The truth of a fact can be only disclosed within the content of scientific theory. For this reason, psychologists should be governed in their practice by the unity of theory, experimentation and social practice.

The paper of Yu. Zabrodin (Moscow), who submitted a system for classification of empirical methods in psychology for discussion by the participants, also dealt with methodological problems of psychological experimentation, questions of correlation between experimentation and theory.

The audience displayed much interest in the problems of engineering psychology and industrial psychology. The scientific and technological revolution is leading to complication of work, which in turn increases the requirements of the subject of labor. For this reason, psychological factors are becoming a most important reserve for the growth of labor productivity. Continued development of engineering psychology makes it imperative to develop a number of methodological problems. This is related, first of all, to the general tendency of development of engineering psychology, the meaning of which consists of turning from the study of separate processes of informational interaction between man and machine to systems analysis thereof. Methodological problems of engineering psychology were the topic of the paper of V. Venda (Moscow) who touched upon the question of mutual adaptation of man and machine, and the problem of an adequate method for describing man-machine systems.

In modern control systems, emotional resistance to stress factors is one of the factors of operator reliability. The paper of L. Kitayev-Smyk (Moscow), "Psychological Aspects of Stress Problems," dealt with the effect of emotional and volitional factors on efficiency and reliability of operator performance. In this paper, he discussed the history of formation of stress theory, the psychological and psychophysiological content of the concept of "stress"; a classification was offered for factors that

determine the occurrence of stress situations. The speaker analyzed the patterns of development of stress, and he singled out the phases of adaptive activity with long-term exposure to stress factors, as applied to operator performance under special conditions.

The study of various professional forms of activity, development of questions of professional guidance and training constitute an important problem of industrial psychology. Methodological problems of research on work activity were touched upon in the paper of V. Shadrikov (Yaroslavl'), "Formation of a Psychological System of Activity."

At the seminars in the section of "Current Problems of Engineering Psychology," the attention of the participants was drawn to problems and methods of mathematical psychology (V. Krylov, Moscow). The logic of development of psychology leads to progressive use of mathematical methods in processing data, modeling mental processes, etc. Mathematical psychology is developing rapidly. Psychological science as a whole is interested in its progress; however, it is of greatest importance to engineering psychology, which is presently making broad use of mathematical models that describe the process of receiving and processing information, and decision making by the operator on its basis.

In the course of the work of the school, there was discussion of a range of issues traditionally related to general psychology, such as problems of cognitive processes, activity and set. The problem of thinking occupied one of the central places in the discussions. In a paper entitled "Problems of Thinking in Modern Psychology," A. Brushlinskiy (Moscow) described in brief the main directions of research in modern psychology of thinking, and he demonstrated the contribution it made to general theory of psychology. He singled out the unity of continuous (nondisjunctive) and intermittent (disjunctive) aspects inherent in living, actual thinking, as the most pressing problem. Experiments convince us, the speaker stated, that thinking as a process is primarily an integral, continuous system, within which various discrete elements are formed and used: formal logical and mathematical operations, etc. The systemic nature of disjunctive operations is implemented by the integral properties of thinking as a continuous process. Such psychological interpretation of continuity differs substantially from its mathematical and cybernetic interpretation. Psychology of thinking strives to disclose the nondisjunctive nature of the thinking process, whereas modern mathematics is merely disjunctive. Consequently, the question arises of the need to create a special branch of mathematics consistent with psychology of thinking.

The paper and seminar of L. Vekker (Leningrad) aroused great interest among the audience. This speaker designated some pressing methodological problems of theory of mental processes, including the means of isolating mental reality proper, the specifics of expressly mental phenomena and methodology of studying them. With reference to such categories as "mental time" and "mental space," L. Vekker stressed the fact that they

could not be compared to physical analogues. Mental time is not the irreversible unidirectional movement from the past through the present into the future, it is a free and subjective movement on the axis of time "forward," into the future (through probabilistic forecasting and anticipatory reflection) and "backward" into the past (by means of the specific mental property, memory). By virtue of the inseparable nature of time and space, there are also changes in the characteristics of mental space.

In this paper, the question of units for measuring psychological elements was listed as another important methodological problem. The study of the unity of gnostic, emotional and volitional processes was proposed as one of the means of creating a system of such units.

Much attention at the seminars was devoted to figurative phenomena: conceptions, imagination, spatial thinking, etc. This is attributable to the increase in share of such problems in experimental psychology related to the needs of social practice. At the present stage of scientific and technological progress, the ability to act on the basis of a conception, to freely operate with spatial images, emerges as one of the valuable individual traits that are needed to master many modern professions and to perform successfully the professional activity itself. Thus, one of the main elements of operator activity is formation of an image of the controlled object on the basis of symbolic information on instruments. Since the image-conception constitutes interpenetration of a graphic image and word, sensory and logical, the problem of conceptions is closely linked with the study of perception and thinking.

The seminar dealing with problems of theory of activity drew a large number of participants. There, questions touched upon in the papers "Prospects of Development of General Psychological Theory of Activity" by V. Zinchenko (Moscow), "Formation of a Psychological System of Activity" by V. Shadrikov and "The Problem of Activity in Soviet Psychology" by K. Abul'khanova-Slavskaya (Moscow) were discussed. They included such questions as self-development and self-determination of activity, correlation between functional need and motivation, the place of motive in the structure of activity, correlation between behavior and activity, as well as problems of units for analyzing mental factors, the study of activity as a subject of research and as an explanatory principle.

A special seminar dealt with some problems of set theory. The interest of the participants in this seminar can be attributed to the fact that theory of set is a psychological conception that strives to describe the integral behavior of man and touches upon many pressing problems of general psychology. However, interpretation of these concepts within the framework of the conception of set differs substantially from interpretation thereof in, for example, theory of activity. While motive emerges as the subjective variable of consciousness, related to incentive, desire, within the framework of the set conception, the proponents of the activity-related

approach interprete motive as the subject of a need. Two opposing positions were also expressed at the seminar concerning the correlation between the categories of activity and set. Georgian psychologists, who represented the school of D. Uznadze, defended the idea of so-called primary set, which anticipates and determines the evolution of any forms of mental activity. Their opponents, holding the methodological positions of the school of L. Vygotskiy, A. Leont'yev and A. Luriya, defended object-related activity as a category that adequately reflects the process of generation of mental phenomena. Most of the participants in the discussion of this issue observed that substantial theoretical contradictions arise when the question of set is considered apart from the activity of a social subject; this proves the need to abandon the isolated, abstract and theoretical study of set phenomena at the present stage of development of Soviet psychology.

Problems of differential psychophysiology and neuropsychology were discussed in a special section. The future [promising] directions of study of neurophysiological bases of man's individuality, within the framework of Soviet differential psychophysiology, were discussed in the paper of V. Rusalov (Moscow), "Current Trends in the Study of the Properties of the Human Nervous System." Summarizing the results of experimental and theoretical research on this problem, V. Rusalov raised the question of multidimensional structure of the man properties of man's nervous system. He stated that serious difficulties are encountered along the way to further development of psychophysiology, which are related to the problem of partial properties of the neural substrate. It consists of the fact that the various properties of the nervous system were found, according to the results of experiments, to differ substantially in different analyzers. For this reason, the problem of isolating common [general] properties of the nervous system emerges as the focal one today for differential psychophysiology. From the standpoint of the systems approach, common properties are apparently individually stable distinctions of integration of nervous processes involved in an integral mental activity. One of the most promising means of searching for common properties of the nervous system is to isolate integral factors of bioelectrical activity of the brain, which characterize the function of different parts thereof. The results of experimental studies demonstrate that there is a close link between these integral factors and certain formal'y dynamic distinctions of human behavior.

The papers and seminars of this section dealt with a wide range of problems of neurophysiological support of mental activity: systemic organization and neurophysiological mechanisms of goal-oriented behavior (V. Shvyrkov, Moscow), prospects of development of neuropsychology (Ye. Khomskaya, Moscow), current neurophysiological approaches to the study of mental processes, the problem of nervous code of mental processes and the problem of sensory prosthetics (A. Shandurina, Leningrad).

To resolve the pressing problems pertaining to formation of the new man, a harmoniously developed personality, one must have a clear idea about the role of psychology in this task. This role can be assessed on the basis of the main theoretical approaches to understanding personality. Current aproaches to studies of personality, with indication of the promising directions of work, were offered in the paper of Ye. Shorokhova (Moscow), "Methodological Problems of Studying Personality," which was delivered in the section "Methodological Problems of Social Psychology." They include the construction of general theory and methodology of studying personality, determination of personality by social relations, ontogenetic development of personality, differential psychology of personality, development and specialization of methods for studying personality, development of personality in the course of activity, etc.

The general trend in development of social psychology in the USSR consists of the fact that this direction of psychological science is being linked more and more closely with the solution of problems of social practice. It is not by chance that the paper delivered by one of the leading specialists in social psychology, Ye. Kuz'min (Leningrad), dealt with the topic of "Social Psychology and Life." The speaker discussed the specific nature of sociopsychological phenomena and laws. At this stage, it was stated in the paper, one of the main tasks for social psychology is to analyze all mental processes from the standpoint of this discipline. Problems of communication, which require development of a number of sociopsychological categories, such as orientation, results and level of communication, are acquiring particular urgency. Also on the agenda are such pressing problems of social psychology as small groups and primary groups [collectives]. Ye. Kuz'min acquainted the audience with some of the possible criteria for evaluating the effectiveness of sociopsychological studies dealing with screening, evaluation and certification of personnel.

The discussion of problems of communication and social perception was continued at the seminars. There, theoretical and practical importance of communication problems was discussed, there was consideration of the various forms, means and functions of communication, levels of analysis thereof (B. Lomov), as well as dynamics of mental functions in communication (V. Koi'tsova, Moscow). There was a comprehensive analysis of the problem of current development of social psychology in capitalistic nations. P. Shikhirev (Moscow) showed that the "privileged" status of social psychology in these countries is attributable chiefly to the desire of the ruling classes to retain their positions by using not only economic and political means of coercion, but psychological mechanisms for controlling people. Freudianism, neo-Freudianism, behaviorism and neosocio-Darwinism emerge as the methodological basis of total manipulation of the awareness [consciousness] of the masses. The paper of S. Roshchin (Moscow), "Ideological and Political Potential of Psychological Science," dealt with a full-fledged critique of these conceptions, as well as issues related to the role of psychology in political life.

Some important issues were touched upon at the seminar on "Social Psychology and Social Practice." There, such problems as formation and development of a new type of social relations in a period of developed socialism, psychological problems of control [management] and others were discussed. For example, A. Zhuravlev (Moscow) discussed the main problems of organization and improvement of performance of administrators on different levels. His idea that social psychology should not be concerned with screening management personnel, but only evaluate and improve their activities inspired an animated discussion. Most of the participants in the seminar were for the active involvement of psychologists in all areas of social practice, including the screening of administrators.

One of the most important directions of psychological science that is traditionally oriented toward practice is child and pedagogic psychology. At the present time, there is increased urgency to further develop the methodology of research in these fields. This is related, first of all, to problems of ontogenetic development of the mind (L. Venger, Moscow), formation and structure of learning activity (V. Davydov, Moscow), methodological problems of organizing studies in age-related and pedagogic psychology (F. Mikhaylov, Moscow). Discussion of these problems drew much attention on the part of the audience.

At the solemn closing meeting of the school, the decision was adopted to convoke similar forums of young scientists on a regular basis. The Second All-Union school for young psychologists will convene in 2 years.

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